INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

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INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

IFYGL BULLETIN NO. 8

OCTOBER 1973

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CANDA

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HIGH ALTITUDE REMOTE SENSING SURVEYS OF LAKE ONTARIO

(IFYGL PROJECT 1F)

Introduction

During the course of the IFYGL, a number of high altitude remote sensing surveys were carried out in order to investigate the time and spatial variations of large scale surface thermal features on Lake Ontario.

The principal objective of the aircraft mission was to obtain complete coverage of Lake Ontario, with an infrared line scanner, on two or more consecutive days.

In order to provide the synoptic coverage of a large lake such as Lake Ontario the infrared line scanner must be flown in an aircraft with a high altitude capability. The aircraft used for these experiments was a Falcon Fan Jet operated by the Canada Centre for Remote Sensing.

The sensor package used for the surveys consisted of a Texas Instruments RS14 line scanner and a Wild RC10 photographic camera. The RS14 line scanner operates in the 8-14 micron band and monitors the thermal emission from the lake surface. The dynamic range of the scanner can be selected and fixed. Thus, the infrared imagery has the capability of providing quantitative information about the scanned terrain.

The main function of the photographic imagery was to provide information on the lake surface features in the visible wavelengths and examine the relationships between these and the infrared imagery.

A total of three missions were flown during the IFYGL field season. These occurred on July 7, August 28 and 29, and October 29. All surveys were flown at an altitude of 10,000 metres. A series of twenty-one flight lines alternating in a north-south mode was sufficient to provide the desired coverage.

The time taken to cover half of the lake was approximately 3 hours, the remainder could only be surveyed after refueling. Thus, the word synoptic applies only to those features which remain relatively unchanged over a time period of several hours. Shorter period variations (see Elder and Thomson, 1970) were not considered in this experiment.

Survey 1 - June 7

Description of the Imagery

A mosaic prepared for the IR data is shown in Figure 1. The most obvious features are the Niagara plume and the thermal bar. Along the north side of

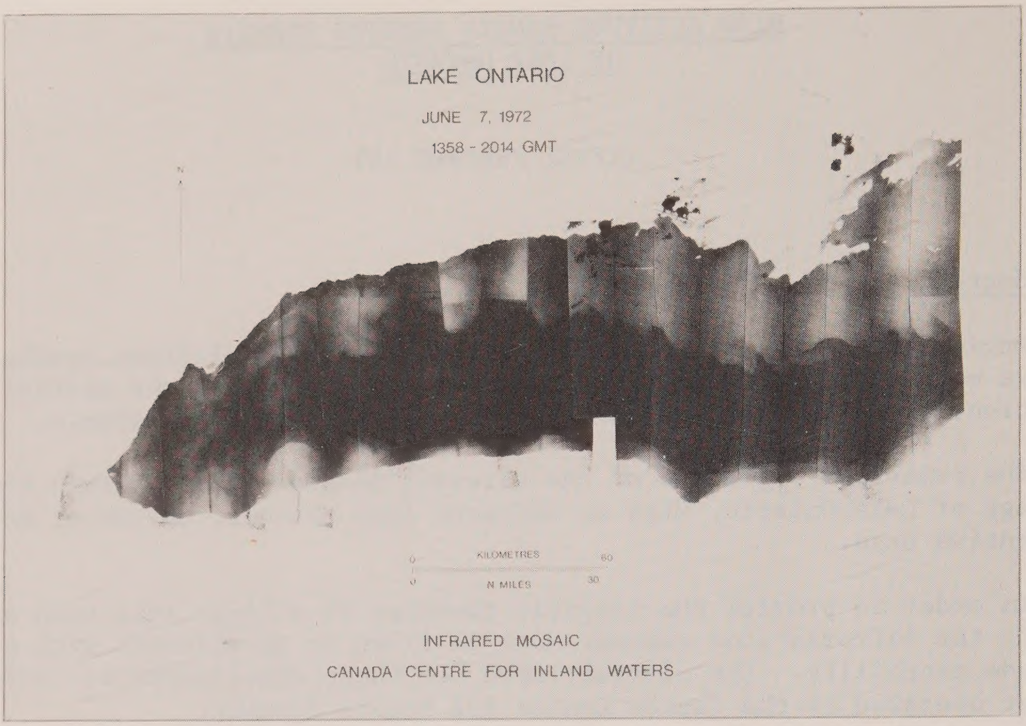

Figure 1.

Figure 2. Surface isotherms prepared from ship data

the lake the thermal bar extends well into the lake. The southern extent of this boundary is in the order of 30 km from the north shore. This particular discontinuity was also observed on the photographic imagery where a significant water colour boundary coincided with the thermal boundary. The thermal gradients on the south shore of the lake are more compressed and exhibit a definite gradation in temperature which shows up as a series of grey tones of the imagery. The mean width of the southern thermal bar is in the order of 5 km.

Another important feature evident on the thermal imagery was a strong upwelling (see Bukata and McColl 1973) condition on the north shore which extended from the Toronto area all the way through to the Prince Edward County.

Also of interest is the fact that the western basin (east of an Oshawa-Niagara axis) shows a much more disordered surface thermal regime than the lake as a whole. While the cause can be attributed to circulation patterns in the western basin this type of inhomogeneity is not always observed by conventional ship data such as shown in Figure 2.

Surface Isotherms

Since the RS14 IR line scanner can be operated with fixed dynamic ranges, a series of densitometric measurements were made on the data in order to exploit the quantitative information contained in the imagery.

When the gain and D.C. level settings of the scanner are constant over a number of flight lines it is possible to compare the scanner film density and relate it to the surface water temperature over the same flight lines.

On the June 7 survey it was possible to compare the film density on the last part of the mission which in essence covers the eastern basin of Lake Ontario.

A number of film density measurements were made along the nadir line on the section of the flight where the gain and D.C. level settings remained constant. Ground truth measurements were used to relate two temperatures to two density values and then the remaining density values were converted into their equivalent temperatures.

The ground truth measurements were obtained from a number of sources, the principal one being the Atmospheric Environment Service airborne temperature survey which occurred on the same day as the overflight. Other water temperature data were available from CCIW ship surveys and the IFYGL meteorological buoy network.

The two base temperatures were taken as 3.0°C and 14.0°C. The lower temperature was relatively easy to correlate with the imagery due to the large areas of 3°C water present at that time of year. The other base temperature was chosen because of a relatively large area of 14°C water which was apparent on the airborne temperature survey.

Figure 3 shows a map of the eastern basin of Lake Ontario with isotherms

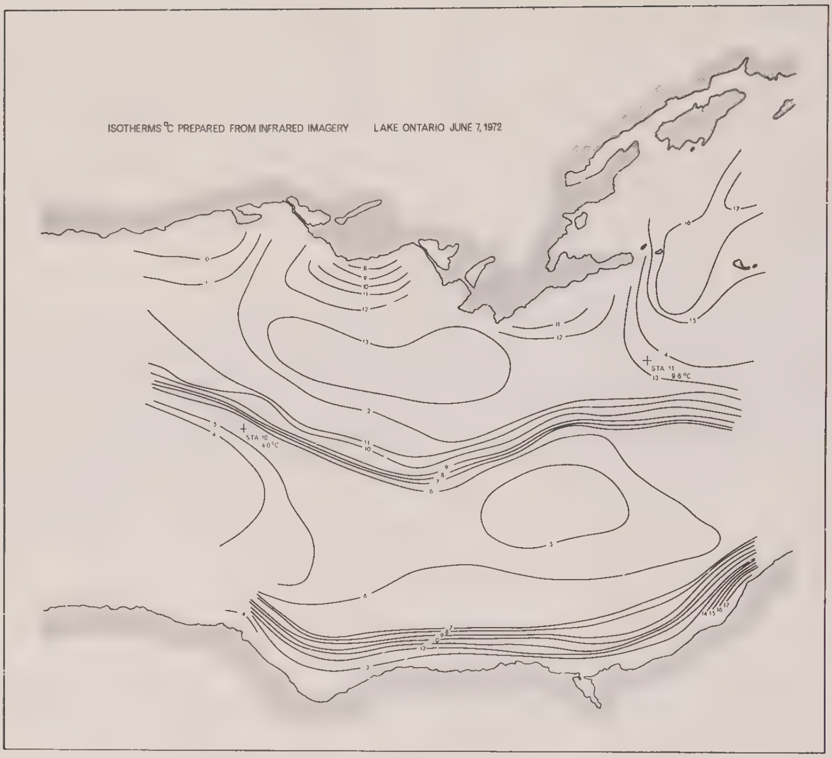

Figure 3. Isotherms in Eastern Lake Ontario prepared from infrared imagery

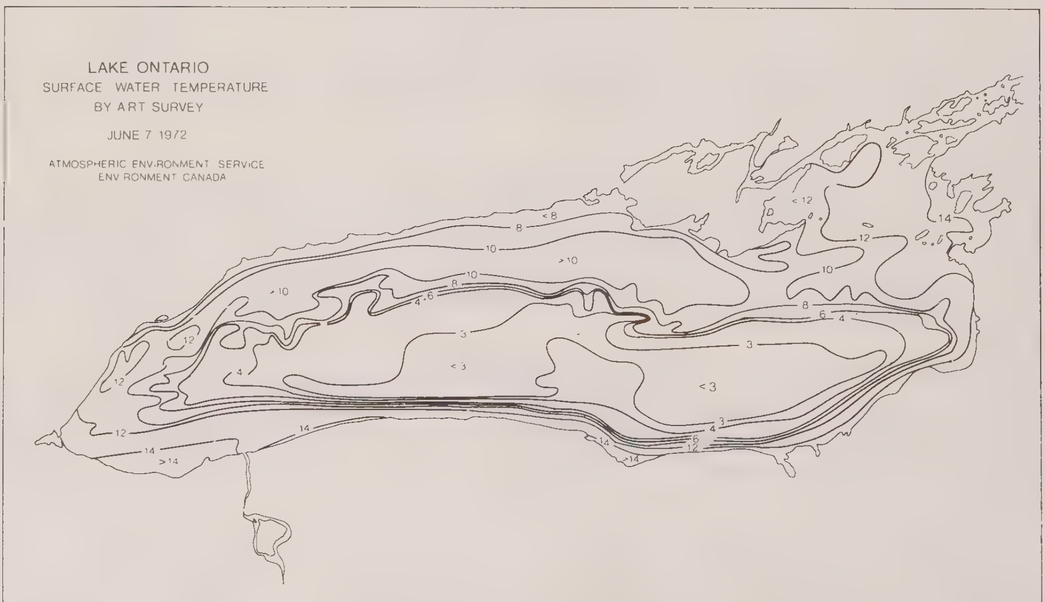

Figure 4. Surface water temperature from Airborne Radiation Thermometer Survey

obtained from the IR imagery. The main temperature features correspond well with the airborne temperature survey (Figure 4) and also the ship survey carried out for June 6-8 (Figure 2), confirms the main features.

The sharp temperature gradients across the north-south portions of the thermal bar are well marked. Some evidence of the upwelling situation is apparent along the north shore where temperatures close to shore are, in general, less than 10°C and increase as one proceeds out from shore. The two meteorological buoy stations 10 and 11 give mean temperature reading of 4.0°C and 9.6°C respectively over the time of the over-flight.

Careful investigation of the errors involved in making quantitative estimates from the RS14 scanner data show that the absolute error, irrespective of atmospheric effects, is in the order of $\pm$ 1.5°C. This rather large error places severe limitations on the interpretations made for the quantitative data. The important point, however, is that the relative temperature structure can be reproduced quite well at least under conditons where a large range of temperature is present.

Meteorological Conditions

The surface temperature structure as observed during the survey is strongly influenced by the meteorological conditions before and during the flight.

By 0300 hrs on June 7, a frontal system had passed through the area leaving Lake Ontario under the influence of a strong north to north westerly flow. Surface winds over the period of the flight were N-NW at 5-8 mps. This N-NW flow had persisted for some 13 hours prior to the flight. Under these conditions strong upwelling along the north shore is to be expected. This steady wind flow would also cause the extension and compression of the surface temperature gradients on the north and south thermal bars respectively.

Survey 2 - August 28 and 29

Description of the Imagery

Figures 5 and 6 show the infrared mosaics prepared from the August 28 and 29 surveys. These two mosaics show Lake Ontario under summer stratified conditions. No large surface temperature gradients, such as appear during the period of the thermal bar, are to be expected under these conditions. The main features observable under stratified conditions are thermal inputs, from rivers or urban areas, and coastal upwelling.

The thermal inputs are observable only when the river water or industrial plume is at a different temperature from ambient. Coastal upwelling, of course, will only occur under certain meteorological conditions.

The two mosaics shown exhibit all these features. The Niagara plume is evident on both days and the influence of the river can be followed along the south shore for some distance. Other smaller thermal inputs or plumes can be seen, i.e. the warm water can be observed streaming out of Toronto Harbour.

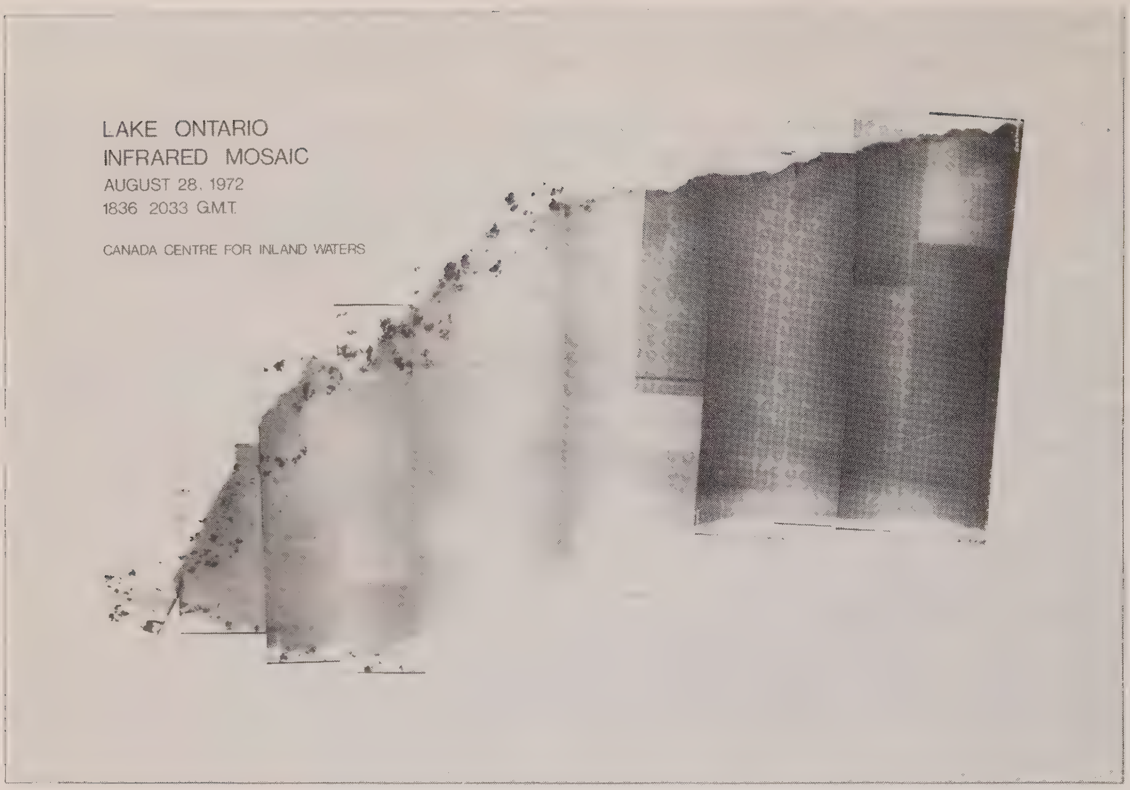

Figure 5

Figure 6

The plume from the Lakeview Hydro plant just west of Toronto can also be observed on the August 28 imagery. There is evidence of upwelling along the north shore on both days.

The lack of grey scale contrasts on the imagery is a reflection of the small temperature range present during this survey. This fact combined with the instrument errors make it unrealistic to attempt the derivation of an isotherm map of the surface temperature for this particular survey. It is, however, constructive to show a plot of isolines of film density for the August 29 data (Figure 7). Without any other temperature data the imagery indicates the lack of large surface temperature gradients. The lower density values along the north shore are an indication of upwelling conditions. This particular condition is confirmed with reference to the airborne radiation thermometer and meteorological buoy data taken during the August 29 survey. A similar comparison for the August 28 data was not possible due to change in the dynamic range of the scanner during the flight.

The most interesting observations on the photographic imagery are the surface streaks indicative of internal wave present on the August 28 and 29 data. On the August 29 imagery these features (see Figure 8) extend from the Toronto area along the north shore to Prince Edward County. The wavelength range associated with the features is between 300 - 1700 metres which is similar to previous observations (Boyce and Thomson, 1972) made from high altitude surveys.

Meteorological Conditions

A relatively strong frontal system had passed into the area by 2100 hrs on August 27. During August 28 the front moved across the lake with surface winds along the north shore varying between north to north west at 5-8 mps. During August 29 the front continued across the lake and by 2100 hrs was well south of the New York coast.

The prolonged N to NW flow is responsible for the upwelling first observed on August 28 and which continued through to August 29. Ground truth measurements show mid-lake temperatures in the order of 19 - 20°C on August 28 with readings of 17.0°C at points on the north shore.

On August 29 conditions were similar with mid-lake temperatures in the range 19 - 21°C. However, the upwelling was more pronounced and temperatures of 16.5°C were observed at points along the north shore.

The Niagara plume as observed on the imagery was warmer than the ambient lake temperatures. Ground measurements on August 28 yield a value of 22.8°C as the highest temperature in the plume. It is interesting to note the influence of the warm Niagara plume along the south shore due to the light westerly wind flow in this part of the lake during the survey period.

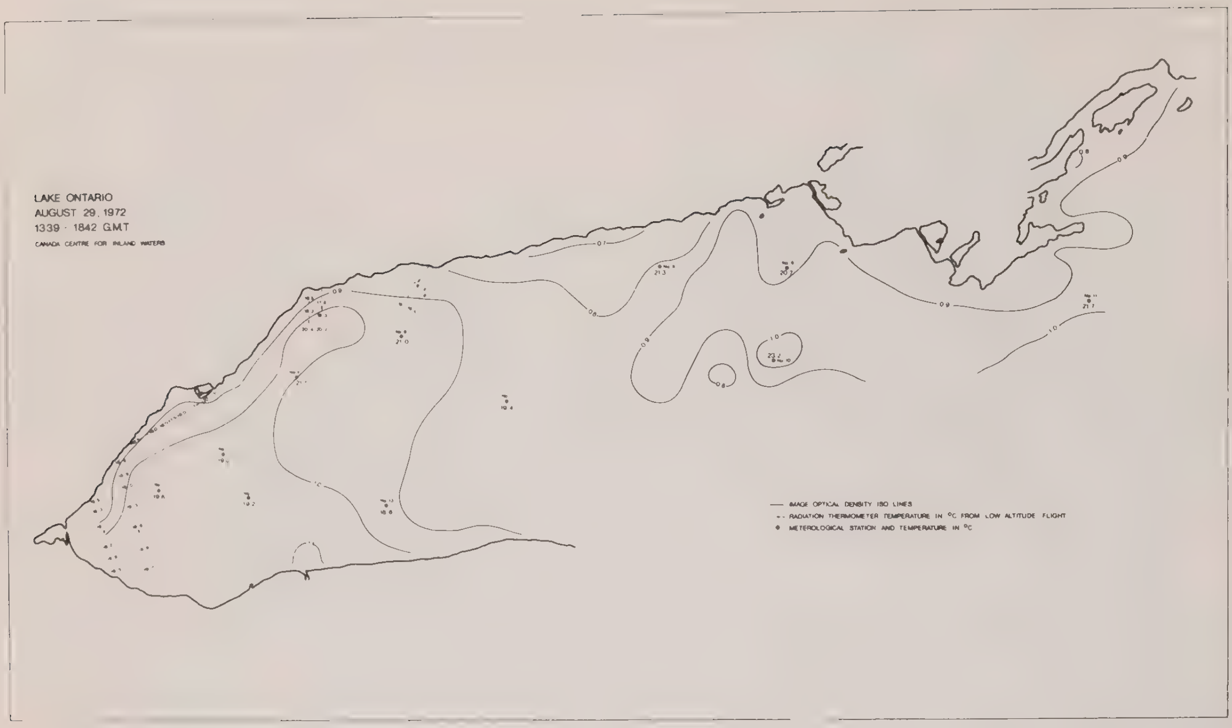

Figure 7. Isolines of infrared film data for August 29, 1972 data

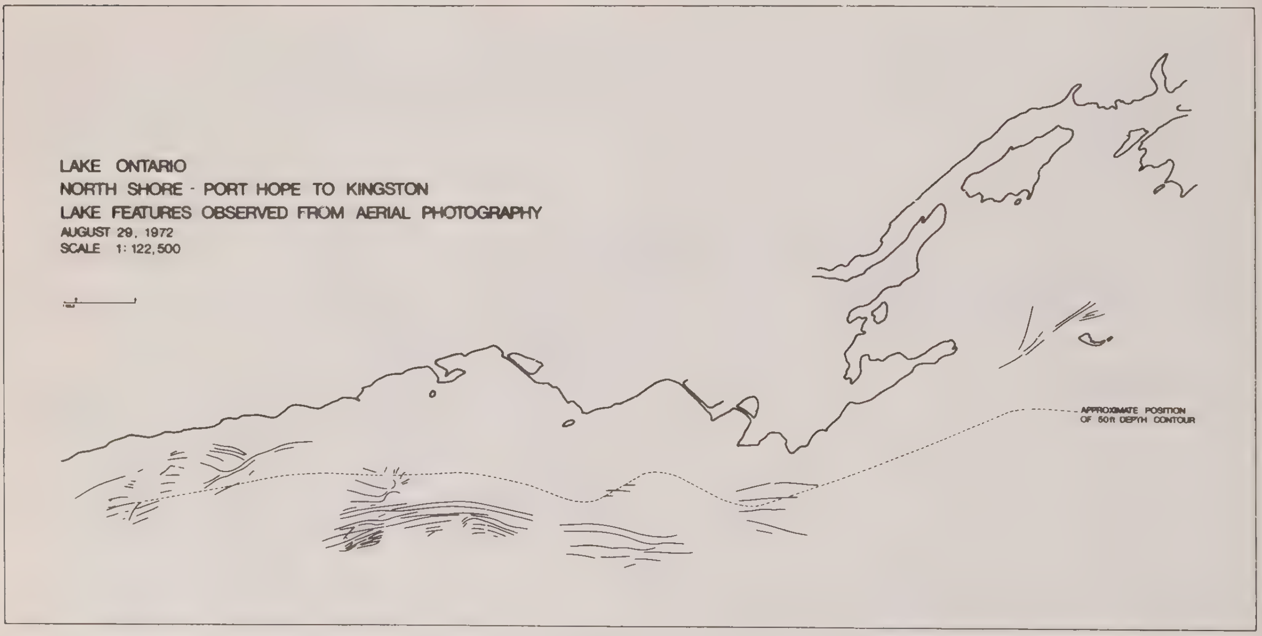

Figure 8

Survey 3 - October 29

Description of the Imagery

The infrared imagery obtained during the mission shows, in general, more surface thermal detail than the August survey (see Figure 9). Due to changes in gain and D.C. level during the flight it was not possible to make densitometric measurements for this survey. The dominant feature on the thermal imagery is the Niagara plume which appears to influence a large part of the western basin. It is interesting to note that while the inner thermal boundary coincides with a sharp water colour boundary on the photographic imagery the outer thermal feature does not correspond to any feature on the visible imagery (see Figure 10). The major shore line turbidity features observed from the photographic imagery are shown in figure 10. The direction of movement, at the time of the overflight is indicated by the solid arrows.

The airborne radiation thermometer survey on October 30 shows very cold surface temperatures in the western basin with temperatures in the order of 5.0^{o}C along the Toronto-Hamilton shore line. Since no major weather system disturbed the area over the period of these two surveys the surface conditions on October 29 would be very similar to those of October 30. The cold temperatures along the Toronto area make features like the thermal plume from the Lakeview plant stand out very clearly on the infrared imagery.

Conclusions

The information contained in the imagery reflects the physical characteristics of the lake at three different periods in the annual cycle. As far as the infrared imagery is concerned, the optimum periods for applying this technique are in early spring, when the lake is starting to stratify, or the autumn when overturning or strong upwelling situations are liable to occur. With consecutive coverage, the infrared survey provides detailed information on the movement of large scale surface features which are controlled by the dynamics of the lake as a whole.

Another important aspect of the large scale surveys is the quantitative information provided by the infrared line scanner. It is evident that the infrared line scanner provides a more realistic indication of the complexities of the surface temperature structure than can be obtained by conventional ship surveys.

The photographic imagery from the large scale surveys has a direct application in the observation of sediment transport on a synoptic scale. This type of information may be of particular value in monitoring the characteristics of turbid effluents in problem areas or in areas, such as the upper Great Lakes, where data gathering by conventional techniques is difficult and expensive.

Figure 9. Infrared mosaic of western basin. October 29, 1972 survey

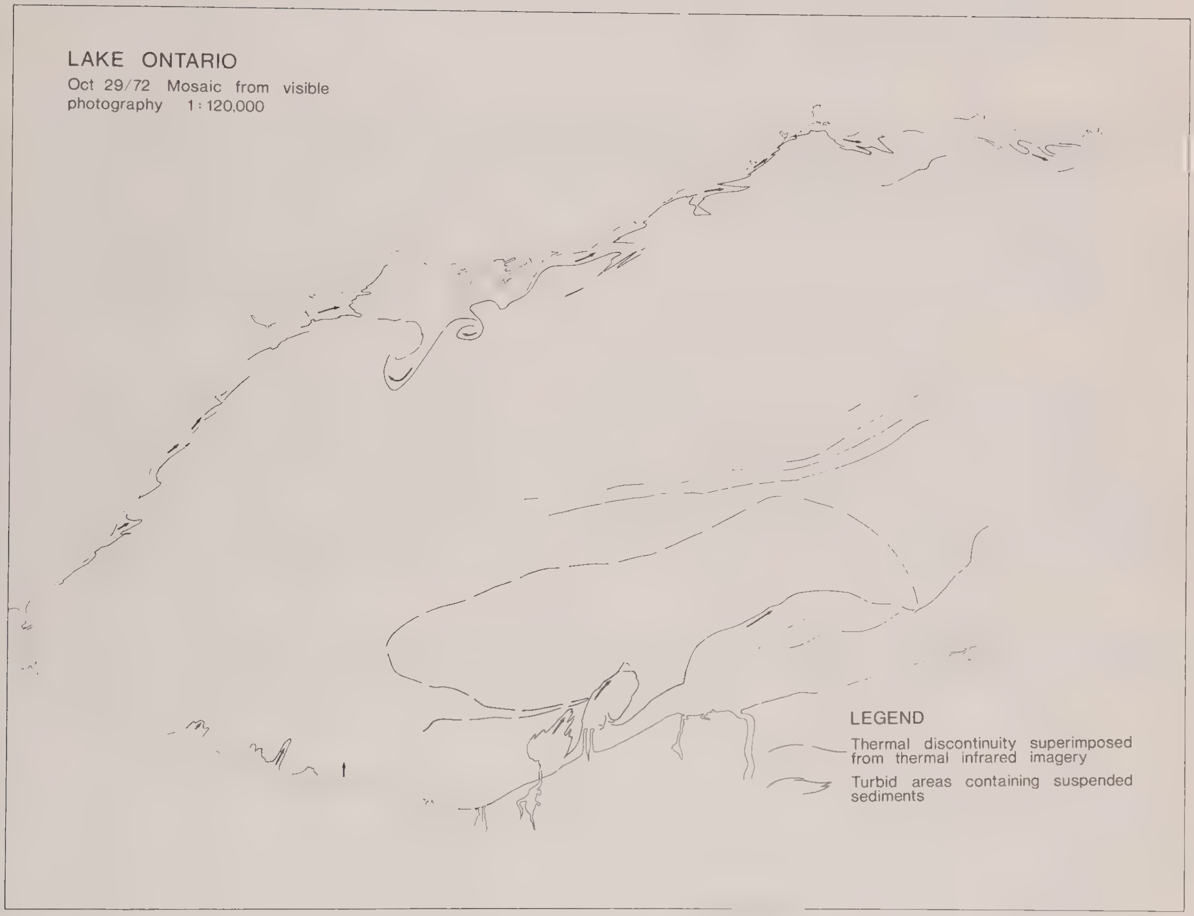
LAKE ONTARIO
Oct 29/72 Mosaic from visible photography 1:120,000
LEGEND
Thermal discontinuity superimposed from thermal infrared imagery
Turbid areas containing suspended sediments

Figure 10

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K. P. B. Thomson.

BOUNDARY LAYER RESEARCH DIVISION
ATMOSPHERIC ENVIRONMENT SERVICE

IFYGL STATUS REPORT - JUNE 1973

Momentum, Heat and Moisture Transfer in the Atmospheric Surface Layer Over Lake Ontario (IFYGL Project 28BL)

Scientists: G. A. McBean, H. C. Martin, R. J. Polavarapu.

Scientific Program

The scientific goal of the program was to investigate the transfers of momentum, heat and moisture in the atmospheric surface layer over Lake Ontario. This includes studies of the transfer mechanisms of the fluxes, the variation of the fluxes over 24 to 48 hour periods, the gradients of wind, temperature and humidity to 12 m, and the energy balance at the water surface. Parameterization of the fluxes in terms of single level observations is also being investigated.

The fluxes were measured directly by two systems: namely, the sonic anemometer - resistance thermometer - Lyman-alpha humidiometer; and sonic anemometer - thermistor - refractometer. Both on-line computation and magnetic tape recording for later digital analysis were used. Cup anemometers were used to measure the wind profile and thermocouples were used for temperature profiles between 1.0 and 12 m. Net radiation and surface water temperature were also measured.

The measurements were made from a bottom-mounted tower installed by CCIW off Niagara-on-the-Lake. The electronics and recording equipment were housed on a CCIW barge about 500 feet from the tower.

The project output will be primarily estimates of the fluxes at one location at selected times plus information on the transfer processes that will aid in deducing the fluxes at other locations and times. In addition detailed analyses of the flux-gradient relations, total and turbulent energy budgets and the statistics of turbulence will be made.

Review of Operations

The spring intensive period was to have been May 1 to 14, 1972. However, because of delays in equipment and cable installation the first data wasn't collected until May 13. The last day of operations in the spring period was May 25. The data was collected with three separate systems. The first was wind and temperature (both dry and wet bulb) profiles which were logged on a punched paper tape system. The anemometers and thermocouples were mounted at 1, 2, 4, 8 and 11 m. The wind profile system started operating on May 13

and was in almost continuous operation until May 25. Examples of the wind and temperature profiles output data is given in Appendix 1. The temperature profile system took much longer to become operational and was not functional until May 18 and then ran until May 24. The data for this period is not complete in that breaks of several hours occur randomly. The data has been analysed in 30 minute periods (32 minute periods for temperature) and the total number of data periods is 541 (270.5 hrs) of wind profiles and 235 (125 hrs) of temperature profiles.

The second system was the sonic anemometer-thermistor refractometer fluxatrons. These measured integrated latent and sensible heat fluxes over 30 minute averages. The first data was collected May 17 and observations continued until May 24. A total of 70 periods (35 hrs) of observation were made. These were generally during the daytime. Net radiation, air temperature (10m), dewpoint (10m) wind speed (10m) and water surface temperature for each period were also observed. An example of the fluxes as measured for May 22, is given as Appendix 2.

The turbulence system used a sonic anemometer-thermometer, platinum resistance thermometer and Lyman-alpha humidiometer and the data was recorded on FM analog tape. About 12 hours of data was collected during the period May 18-25 with most being collected on May 19, 20, 22. A tabulation of the data collected is given as Appendix 3. The data will be digitized and statistically analysed.

The October intensive period was October 1-14. This fall intensive period was also delayed somewhat. The main problems were in the cables between the barge and the tower. These cables were laid the first week of May and by October had been severly damaged by the continual motion of the barge. For this reason the observational program in October was quite curtailed. The wind profile system was in operation almost continuously from October 5-14 but the temperature profile systems were not operated at all. The temperature system required 110 VAC to operate the aspirator motors. Unfortunately the 110 VAC power cable was broken during the summer and a replacement cable was also broken within a day of laying it at the beginning of October. The type of wind profile data for October will be as per Appendix I and a total of 398 periods (199 hrs) was collected.

Through a variety of cable improvisations it was possible to operate the fluxatron systems for a total of 20 hrs on October 6, 10, 11, 12, 13. The main trouble was with the sonic anemometer cable which had some intermittent breaks. About 5½ hours of turbulence data was collected on FM analog tape on October 10, 11, 13. For two of those hours the sonic anemometer horizontal wind channels were not working. A summary of the data collected is given in Appendix 3.

Summary of Progress and Future Plans

The data from the fluxatron systems has all been analysed and papers based on it were presented by H. C. Martin at the IFYGL Symposium at the Great Lakes Research Conference at Huron, Ohio and at the National Congress of the Canadian Meteorological Society, Halifax, May 30 - June 1. Abstract of one

presentation is given as Appendix 4.

The profile data has undergone the initial analysis stage (as seen in Appendix I) and will be further analysed as per the scientific program in the next few months. The turbulence data has been scrutinized and will be digitized and statistically analysed in the next few months.

Calendar summaries of the data by days are given in Appendix 5. A more complete data report of this program's results will be available by October 1. The main data of interest to the program scientists are other results of the Niagara Bar experiment and nearby tower and shore data.

T-33 Airplane Investigations of the Boundary Layer (IFYGL Project 15BL)

Scientists: G. A. McBean, E. G. Morrissey (Small Scale Processes Research Division)

Scientific Program

This is a project to investigate the micro and mesoscale variations within the boundary layer over Lake Ontario. The goals are to estimate the spatial variations of wind and temperature over a scale range of 1 to 100 km and to investigate the horizontal and vertical variation of the fluxes of momentum, heat and moisture. The T-33 airplane, operated by and in cooperation with the National Aeronautical Establishment, Ottawa, was flown in flight patterns of long legs at one level both along and cross wind as well as shorter legs near one location at a series of levels between 20 and 300 m.

Power spectral analyses of Doppler winds, temperature and flux data will be carried out to investigate the mesoscale variations. The wind data will be corrected for side-slip. The fluxes will be averaged over 1 km legs before the spectra are computed.

The turbulence sensors have been used to calculate the fluxes of momentum heat, and moisture. Power spectral analysis of these data will also be done.

The end products will be a number of estimates of the spatial spectra of temperature, wind and the three fluxes and estimates of the fluxes at different locations and elevations. The statistics of the turbulence and their variation in the horizontal and vertical will also be investigated.

Review of Operations

All the T-33 flights were made in the fall of 1973. A total of 8 flights were made but only five will be analysed for this project. The flights were according to the flight tracks given in Appendix 6 except for flight 8 which was a box pattern over the middle of Lake Ontario and flown December 13. The other flights were October 8, 9, 12 and 15. This program is being analysed initially in two separate parts. The slower response instrumentation such

as Doppler winds, mean temperatures etc. are being analysed for mesoscale studies by the Small Scale Processes Research Division under E. G. Morrissey The faster response turbulence data is being analysed by G. McBean in the Boundary Layer Research Division.

Summary of Progress and Future Plans

The turbulence data has all been corrected for aircraft motion and tapes of u', v', w', T', q' have been computed for each flight segment. Simultaneous to creating the tapes the relevant covariances uw, wT, wq etc. were computed by direct cross products. Examples of these outputs and data summary are given in Appendix 5. A total of 92 flight segments at altitudes from 25 to 300m were analysed. Most were at flight level about 150m. The analysis of the data will continue with emphasis on turbulence structure and variation in vertical and horizontal and examination of details of synoptic events. For the latter in particular the surface analyses, IFYGL buoy and shore network and radiosonde data for the appropriate days are needed.

Appendix 1

Wind Profiles - (19 May, 1972) In M/S Averaged Over 30 Min Previous To The Indicated Times.

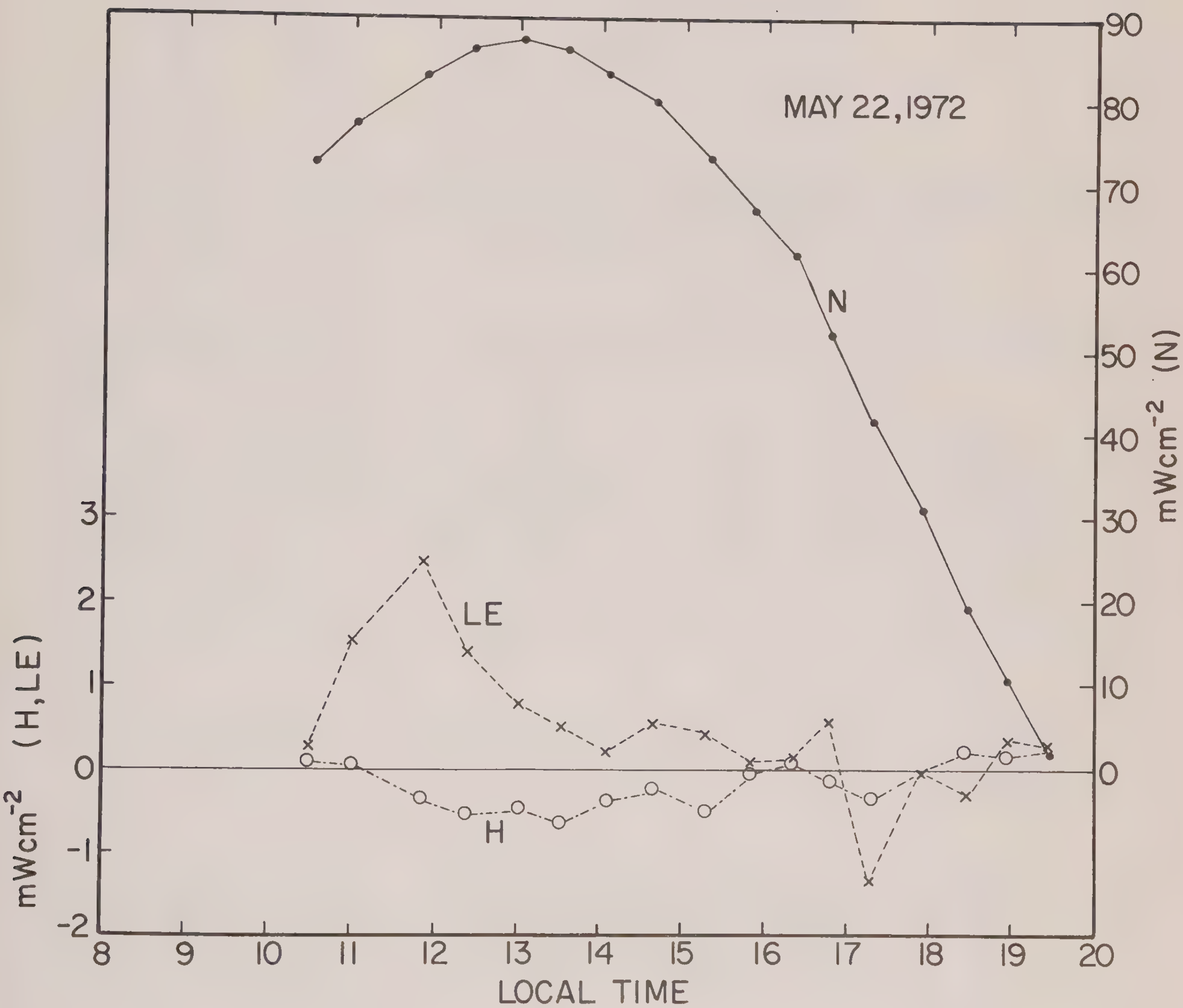
TIME (EDT)	Height of Sensor				
	1M	2M	4M	8M	12M
0030	1.14	1.16	1.29		1.30
0100	.84	.90	1.03		1.08
0130	.50	.54	.65	.66	.66
0200	.64	.72	.78	.81	
0230	1.06		1.19	1.36	1.41
0300	1.03	1.06	1.16	1.34	1.37
0330	.74	.86	.90	.92	.94
0400	1.95	2.04	2.17	2.20	2.25
0430	1.51	1.56	1.70	1.70	1.83
0500	1.22	1.26	1.39		1.40
0530	.87	.93	1.02		
0600	2.45	2.54	2.68	2.71	2.75
0630	.97	1.03	1.13	1.13	1.17
0700	1.46	1.49	1.63		
0730	1.74	1.76	1.99		
0800	1.72	1.78	1.88		
0830	1.42	1.49	1.60		
0900	1.32	1.35	1.48		1.48
0930	1.60	1.64	1.76	1.76	1.83
1000	2.00	2.07	2.22	2.34	2.51
1030	2.98	3.25	3.36	3.71	4.41
1100	3.84	4.21	4.40	4.89	5.76
1130	4.21	4.53	4.76	5.27	6.03
1200	4.62	4.93	5.24	5.81	6.33
1230	4.99		5.81		
1300	4.47	4.85	5.08	5.64	6.27
1330	4.65		5.56		
1400	6.10		7.96		
1430	3.91	4.34	4.54	5.22	6.14
1500	2.86	3.24	3.42	3.90	4.78
1530	1.78	2.10	2.34	2.78	3.51
1600	2.47	2.78	3.04	3.45	4.04
1630	2.81	3.12	3.32	3.74	4.35
1700	1.61	1.89	1.95	2.20	2.93
1730	2.48	2.89	3.12	3.60	4.41
1800	1.95	2.28	2.45	2.85	3.63
1830	2.04	2.34	2.52	2.91	3.68
1850	2.28	2.59	2.70	2.95	3.78
2130	1.56	1.66	1.93	2.24	2.46
2200	1.48	1.59	1.84	2.03	2.20
2230	.49	.59	.61	.71	.80
2300	.70	.80	.88	.89	.90
2330	1.35	1.43	1.64	1.72	1.76

Appendix I (Continued)

Temperature Profiles - (19 May, 1972). Temperature Differences are 1. Calculated from Lower Height Temperature - Upper Height Temperature. 2. Averaged Over 32 Min. Following the Specified Time. 3. In Degrees Celsius.

TIME (EDT)	DRY BULB DIFFERENCE				WET BULB DIFFERENCE			
	1-2M	2-4M	4-8M	8-12M	1-2M	2-4M	4-8M	8-12M
0025	.42	-.45	-.31	-.42	.75	.32	.27	.34
0110	.24	-.45	-.31	-.43	.67	.24	.21	.25
0142	1.30	-.40	-.32	-.44		.36	.32	.35
0214	.47	-.43	-.32	-.44	.98	.36	.29	.33
0246	.38	-.44	-.29	-.45	.88	.33	.28	.32
0318	1.03	-.42	-.31	-.41	1.04	.36	.29	.34
0355	.78	-.45	-.31	-.41	.81	.30	.28	.33
0427	.41	-.45	-.30	-.42	.61	.31	.27	.32
0459	.29	-.45	-.25	-.43	.39	.28	.25	.30
0520	-.22	-.45	-.32	-.38	.43	.32	.30	.36
0552	-.71	-.53	-.31	-.42	.15	.22	.25	.30
0645	-1.11	-.48	-.31	-.42		.30	.30	.30
0717	-1.04	-.51	-.27	-.40		.23	.30	.31
0812	.03	-.06	.18	-.04	.02	.14		.13
1025	-.31	-.35	-.32	-.37	.15	.16	.13	.12
1057	-.23	-.29	-.29	-.31	.17	.19	.17	.12
1129	-.23	-.28	-.21	-.21	.19	.22	.20	.14
1205	-.26	-.30	-.32	-.39	.16	.16	.12	.08
1237	-.27	-.29	-.32	-.36	.16	.16	.12	.07
1400	-.25	-.20	-.47	-.77	.22	.34	.45	.75
1432	-.23	-.18	-.37	-.40	.22	.24	.27	.31
1504	-.19	-.12	-.40	-.20	.21	.25	.27	.13
1536	-.22	-.20	-.37	-.29	.17	.20	.17	.14
1608	-.21	-.21	-.31	-.33	.15	.16	.12	.10
1640	-.16	-.14	-.31	-.17	.13	.17	.17	.09
1712	-.16	-.09	-.38	-.07	.15	.22	.35	.16
1744	-.20	-.15	-.52	-.05	.14	.20	.39	.30
1816	-.16	-.17	-.21	-.25	.18	.21	.19	.05
1910	-.23	-.25	-.27	-.36	.14	.15	.10	.14
1942	-.21	-.20	-.28	-.29	.17	.20	.17	.22
2030	-.14	-.06	-.30	-.10	.20	.27	.33	.25
2102	-.17	-.16	-.19	-.13	.18	.21	.22	.21
2134	-.17	-.17	-.18	-.17	.17	.19	.17	.18
2206	-.17	-.18	-.17	-.19	.16	.18	.15	.18
2238	-.18	-.18	-.16	-.19	.15	.16	.14	.16

Appendix 2


MAY 22, 1972
N
LE
H
mWcm^{-2} (H, LE)
mWcm^{-2} (N)
LOCAL TIME
3
2
1
0
-1
-2
8
9
10
11
12
13
14
15
16
17
18
19
20
90
80
70
60
50
40
30
20
10
0

Appendix 3

Turbulence System Data Summary. A,B,W are sonic anemometer A,B,W. A and B winds in horizontal plane, W is vertical. T_s, T_p, T_T are temperatures from sonic thermometer, platinum resistance thermometer and thermistor respectively. q is Lyman-alpha humidiometer. R is refractometer.

Run	Start Time	Duration	Parameters	Comments
May period				
1	18/1040	60	A,B,W,T_s,T_p	stable to neutral, light winds
2	19/1147	65	"	neutral, wind 5 m/s
3	19/1457	66	"	neutral, light winds, east
4	19/1726	65	A,B,W,T_s,T_p,q	neutral, light winds, north
5/1	19/1912	33	"	neutral, light winds, north
5/2	20/1019	33	"	unstable, wind 3m/s, NE
6/1	20/1213	29	"	unstable, wind 4m/s east
6/2	20/1327	37	"	unstable, wind 2m/s NE
7	21/1351	68	"	neutral, light north
8	22/1008	67	"	unstable, 6m/s N
9	22/1256	65	A,B,W,T_s,T_p,q	unstable, 5 m/s N
10	22/1256	68	A,B,W,T_s,T_p,q,R	stable 6 m/s N
11	22/1512	52	"	stable, variable winds
12	25/0956	60	A,B,W,T_s,T_p	neutral, 13 m/s, NE
October				
1/1	10/1717	19	A,B,W,T_s,q,R	some bad sections
1/2	10/1745	43	"	some bad sections
2	10/1835	67	"	
3	10/1953	67	"	
4/1	10/2119	32	"	not very good data
4/2	11/1550	35	T_T,q,R	no sonic anemometer
5	13/0927	63	B,W,T_s,q,R	no sonic A, not too good
6	13/1305	38	W,T_s,q,R	no A,B.

Appendix 4

Abstract

During six days in May and four days in October 1972, net radiation (n), sensible (H) and latent (LE) heat flux were measured directly on a tower in Lake Ontario. Over one hundred half-hour runs were made.

In May both H and LE are small, of the order of 2 mW cm^{-2}, and the energy budget is overwhelmingly dominated by N with a daytime average of over 50 mW cm^{-2}. This incoming energy is used to heat the lake. At night all components are close to zero.

In October H and LE are positive in the unstable conditions with average values throughout the twenty-four hour period of 5 mW cm^{-2} and 11 mW cm^{-2}, respectively. The average rate of cooling of the lake is estimated at about 13 mW cm^{-2} which is higher than other estimates.

The evaporation rate in October is 11.1 cm $month^{-1}$, in good agreement with other estimates based on indirect measuring techniques.

Appendix 5

Investigator: R. J. Polavarapu — Platform: Niagara tower - wind (u) and temperature profiles (T)

May	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	u	u	u	u	u	u,T	u,T	u,T	u,T	u,T	u,T	u,T	u	
October	1	2	3	4	5	6	7	8	9	10	11	12	13	14
					u	u	u	u	u	u	u	u	u	u

Investigator: H. C. Martin — Platform: Niagara tower - latent and sensible heat fluxatrons

May	13	14	15	16	17	18	19	20	21	22	23	24	25	26
					X	X	X	X	X	X	X	X		
October	1	2	3	4	5	6	7	8	9	10	11	12	13	14
					X					X	X	X	X	

Investigator: G. A. McBean — Platform: Niagara tower - turbulence data

May	13	14	15	16	17	18	19	20	21	22	23	24	25	26
						X	X	X	X	X			X	
October	1	2	3	4	5	6	7	8	9	10	11	12	13	14
										X	X		X	

Appendix 6

NAE-T-33 Flight Summary

Flt.	Date	Time (E.D.T.)	Flight Pattern	Comments
1	Oct. 4	1250-1410	1	Check-out - not complete
		1507-1540	2	
2	Oct. 8	1012-1110	1	good winds
		1344-1455	2	
3	Oct. 9	1019-1114	1	good winds
		1300-1400	2	large q fluct.
4	Oct. 10	1411-1430	Comparison with NCAR Buffalo	
5	Oct. 12	1250-1350	1	good q fluct.
		1557-1703	2	
6	Oct. 15	1025-1125	1	fairly light winds
		1340-1440	2	
7	Oct. 16	1120-1310	3	Ottawa-Sarnia-Ottawa
8	Dec. 13		Box Pattern	

In the following data summary (Table 1) the units are m sec^{-1}, ^{o}C or g/kg.

TAS - true air speed

SIGU, SIGV, SIGW, SIGT, SIGH are the r.m.s. values of u,v,w,T, and H (humidity) fluctuations.

Table 1. IFYGL T-33 Flights Data Summary

NO.	FLIGHT	SEGM	ALTI-TUDE	WIND SPEED	WIND DRCN.	AVG. T	R.H.	TAS	SIGU	SIGV	SIGW	SIGT	SIGH	UW	WT	WQ
1	2	AB1	156.6	10.92	250.	286.6	67.	128.6	.95	.80	.68	.08	.08	-.173	.016	.023
2	2	AB2	156.2	12.00	263.	286.4	68.	128.5	1.26	1.02	.83	.06	.06	-.386	.004	.014
3	2	AB3	151.2	11.12	275.	286.0	66.	128.3	.71	.65	.67	.08	.01	-.108	.024	.044
4	2	AB4	157.4	12.26	291.	286.2	63.	128.5	1.00	.81	.59	.17	-.00	-.195	-.016	.033
5	2	BC	160.5	14.16	295.	287.5	61.	128.2	.79	.69	.55	.04	.11	-.119	-.006	.025
6	2	CD	154.0	13.13	274.	286.8	67.	129.8	.77	.67	.56	.06	.10	-.088	-.001	.025
7	2	DE1	150.6	12.05	284.	286.7	64.	129.6	.90	.86	.67	.07	.14	-.152	.001	.040
8	2	DE2	161.1	15.65	302.	286.8	52.	129.7	1.66	1.35	1.27	.11	.10	-.682	.058	.049
9	2	ED1	165.4	15.24	307.	286.6	52.	134.2	1.80	1.39	1.14	.07	.09	-.611	-.005	.024
10	2	ED2	154.9	14.21	286.	287.3	62.	130.0	.99	.85	.66	.07	.15	-.194	-.006	.043
11	2	B10	303.6	15.35	298.	286.9	38.	132.7	.69	.59	.53	.05	.14	-.061	-.003	.022
12	2	C10	297.9	14.11	306.	286.9	41.	130.8	.66	.63	.55	.04	.16	-.151	-.002	.048
13	2	B05	153.7	15.40	303.	288.0	35.	133.0	.85	.68	.55	.04	.20	-.104	-.004	.044
14	2	C05	161.0	14.37	298.	288.1	39.	129.4	1.02	.76	.65	.04	.24	-.293	.009	.092
15	2	B02	65.2	16.43	303.	289.0	36.	130.1	1.07	.92	.54	.04	.24	-.119	-.004	.049
16	2	C02	64.0	15.35	301.	289.0	38.	125.5	1.01	.83	.53	.04	.32	-.247	.002	.083
17	2	B01	25.9	12.72	291.	289.4	38.	125.8	1.19	.91	.57	.06	.32	-.325	.014	.095
18	2	C01	27.2	13.34	311.	289.3	38.	129.1	1.23	.86	.56	.07	.37	-.279	.008	.099
19	2	AD1	153.1	15.45	296.	288.1	37.	130.3	.86	.66	.58	.04	.23	-.219	.001	.072
20	2	AD2	154.7	18.69	290.	288.0	38.	130.1	1.01	.70	.60	.04	.22	-.185	-.004	.049
21	2	AD3	152.7	19.47	289.	288.0	38.	130.4	1.02	.78	.67	.04	.24	-.261	.004	.067
22	2	AD4	156.1	19.57	286.	288.2	38.	130.3	1.17	.98	.83	.05	.22	-.357	.009	.077
23	2	AD5	157.3	16.63	292.	288.1	40.	132.4	.96	.83	.76	.07	.21	-.247	.016	.083
24	3	AB1	153.1	14.01	250.	279.2	43.	129.3	1.17	1.18	1.08	.13	.14	-.335	.073	.082
25	3	AB2	162.8	11.59	310.	278.9	43.	128.0	1.24	1.47	.96	.14	.09	-.333	.066	.036
26	3	AB3	154.0	12.46	323.	279.6	42.	125.7	1.05	1.04	.87	.10	.11	-.059	.016	.043
27	3	AB4	153.6	10.25	319.	279.6	48.	126.8	.83	.78	.66	.06	.09	-.157	.007	.027
28	3	BC	152.0	11.53	300.	280.1	49.	124.5	.89	.86	.90	.09	.16	-.040	.052	.081
29	3	CD	152.1	10.09	310.	279.9	55.	127.8	.80	.86	.85	.10	.18	-.077	.051	.092
30	3	DE1	156.1	10.40	323.	279.7	48.	125.1	.69	.63	.64	.07	.12	-.082	.019	.037

Table 1. (Continued) IFYGL T-33 Flights Data Summary

NO.	FLIGHT	SEGM	ALTI-TUDE	WIND SPEED	WIND DRCN	AVG T	R.H.	TAS	SIGU	SIGV	SIGW	SIGT	SIGH	UW	WT	WQ
31	3	DE2	176.5	11.28	318.	278.3	50,	127.7	1.30	1.23	1.05	.11	.04	-.360	.050	.020
32	3	ED1	169.1	10.09	317.	277.9	52.	130.6	1.16	1.04	.94	.13	.05	-.312	.047	.023
33	3	ED2	155.4	10.50	308.	279.8	49.	124.7	.77	.72	.76	.08	.14	-.110	.032	.061
34	3	B10	298.0	6.75	300.	280.1	48.	126.8	.70	.74	.83	.06	.10	-.006	.022	.040
35	3	BO5	145.4	6.54	314.	281.7	44.	125.9	.88	.75	.80	.08	.16	-.079	.037	.070
36	3	CO5	145.4	8.86	305.	281.8	42.	125.6	.79	.88	.78	.09	.18	-.150	.041	.084
37	3	BO2	60.4	9.01	307.	282.6	42.	124.9	.80	.71	.60	.11	.21	-.060	.035	.072
38	3	CO2	60.5	10.35	299.	282.7	40.	125.6	.81	1.04	.65	.14	.27	-.132	.051	.103
39	3	AD1	144.5	9.32	300.	281.9	41.	125.8	.77	.75	.83	.09	.20	-.095	.051	.107
40	3	AD2	145.7	12.05	301.	281.4	48.	126.5	.86	.78	.88	.09	.20	-.229	.045	.101
41	3	AD3	148.9	13.44	302.	281.4	45.	124.9	.78	.85	.81	.10	.20	-.163	.045	.095
42	3	AD4	148.7	12.26	305.	281.0	41.	125.5	.74	.71	.69	.08	.19	-.141	.021	.069
43	5	AB1	155.1	7.98	14.	290.1	60.	127.4	.63	.52	.39	.05	.06	-.063	-.001	.008
44	5	AB2	153.2	7.21	340.	290.6	55.	128.9	1.02	1.00	.70	.08	.07	-.256	.018	.018
45	5	AB3	148.9	8.45	331.	290.5	51.	128.8	.49	.52	.35	.05	.07	.002	-.001	-.000
46	5	AB4	154.1	8.34	318.	288.7	64.	128.0	.36	.37	.22	.06	.04	-.007	-.002	.002
47	5	BC	152.9	9.42	302.	288.0	65.	128.5	.21	.23	.13	.03	.02	.004	-.000	.000
48	5	CD	152.7	10.71	293.	287.9	69.	126.9	.14	.15	.13	.02	.01	.003	.000	.000
49	5	DE1	161.8	8.81	313.	288.7	65.	127.3	.36	.34	.19	.05	.04	.008	-.002	.002
50	5	DE2	163.4	8.34	338.	287.9	56.	130.8	.90	.70	.64	.07	.07	-.211	.020	.017
51	5	ED1	163.7	9.53	334.	287.5	56.	131.5	.98	.77	.65	.06	.07	-.211	.009	.015
52	5	ED2	160.5	10.14	299.	288.5	65.	127.7	.23	.22	.13	.04	.03	.007	-.001	.001
53	5	B10	292.8	7.31	337.	285.1	63.	130.3	.46	.48	.40	.04	.06	-.010	-.003	.011
54	5	C10	290.5	10.09	343.	285.4	59.	129.8	.34	.33	.28	.04	.11	-.007	-.001	.010
55	5	BO5	159.4	9.11	345.	286.2	58.	127.0	.49	.44	.39	.03	.08	-.037	.004	.015
56	5	CO5	162.4	9.94	329	286.5	57.	127.1	.49	.41	.45	.03	.14	-.097	.005	.039
57	5	BO2	65.1	10.50	337.	287.1	56.	129.0	.65	.53	.43	.04	.13	-.098	.005	.028
58	5	CO2	61.9	10.20	330.	287.2	55.	127.8	.63	.59	.46	.07	.17	-.145	.016	.043
59	5	BO1	30.3	8.60	339.	287.0	55.	127.7	.75	.51	.38	.07	.16	-.130	.016	.033
60	5	CO1	29.7	10.76	343.	287.3	55.	126.8	.78	.74	.41	.07	.21	-.137	.017	.048
61	5	AD1	149.7	12.26	336.	285.5	54.	128.1	.47	.45	.47	.04	.14	-.084	.005	.036

Table 1. (Continued) IFYGL T-33 Flights Data Summary

NO.	FLIGHT	SEGM	ALTI-TUDE	WIND SPEED	WIND DRCN	AVG T	R.H.	TAS	SIGU	SIGV	SIGW	SIGT	SIGH	UW	WT	WQ
62	5	AD3	155.8	11.43	321.	286.4	56.	129.6	.57	.36	.28	.06	.13	-.024	-.003	.006
63	5	AD4	154.5	3.91	11.	286.5	64.	127.6	.50	.59	.37	.04	.05	-.059	.000	.007
64	6	AB1	155.4	7.05	327.	277.4	50.	125.9	.95	.95	.90	.12	.09	-.214	.066	.043
65	6	AB2	166.3	7.42	312.	277.6	42.	127.0	1.21	1.03	1.01	.15	.06	-.538	.090	.028
66	6	AB3	150.6	5.46	315.	278.2	38.	126.5	.69	.71	.60	.06	.08	-.027	.012	.022
67	6	AB4	151.1	4.48	301.	278.0	50.	125.6	.53	.61	.45	.06	.12	-.016	.000	.018
68	6	BC	148.3	2.78	281.	278.1	51.	123.0	.54	.51	.59	.07	.14	.058	.015	.040
69	6	CD	150.3	4.38	301.	278.6	42.	124.3	.66	.64	.66	.06	.10	-.048	.022	.032
70	6	DE1	155.6	4.89	291.	277.9	49.	124.2	.55	.57	.51	.05	.10	.007	.008	.025
71	6	DE2	166.8	6.44	319.	278.4	34.	127.4	.99	.91	.78	.11	.09	-.165	.036	.022
72	6	ED1	160.2	5.05	292.	277.6	45.	129.1	.69	.69	.58	.06	.07	-.062	.002	.016
73	6	ED2	161.4	6.08	262.	278.0	49.	126.2	.51	.54	.56	.05	.11	.007	.014	.034
74	6	C10	291.7	8.08	306.	279.3	49.	130.0	.89	.85	.79	.06	.17	-.227	.011	.063
75	6	B10	282.9	9.84	302.	279.8	40.	127.4	.81	.74	.96	.06	.09	.145	.035	.042
76	6	CO5	159.1	7.57	296.	280.4	49.	126.2	.83	.89	.82	.08	.18	-.220	.037	.082
77	6	BO5	158.7	8.96	303.	281.5	37.	127.6	.76	.68	.71	.06	.10	-.055	.024	.039
78	6	BO2	66.1	10.50	308.	282.2	36.	125.8	.78	.77	.60	.09	.14	-.079	.029	.046
79	6	CO2	60.4	9.27	288.	282.1	41.	126.1	.82	.91	.68	.12	.20	-.182	.040	.066
80	6	CO1	23.9	3.09	232.	282.6	42.	123.9	.88	.98	.49	.17	.28	-.118	.050	.075
81	6	AD1	155.1	9.63	290.	281.5	40.	126.5	.83	.80	.85	.09	.14	-.106	.042	.066
82	6	AD2	157.7	7.47	276.	280.0	53.	125.4	.68	.63	.68	.07	.13	-.093	.022	.044
83	6	AD3	156.6	10.04	277.	279.6	48.	125.4	.71	.64	.71	.06	.09	-.046	.029	.038
84	6	AD4	157.7	10.40	273.	279.8	42.	127.2	.87	.84	.88	.10	.12	-.079	.049	.059
85	8	BX1	47.5	13.70	282.	277.3	53.	130.8	.79	.71	.58	.09	.20	-.194	.030	.068
86	8	BX2	47.2	11.64	286.	277.5	56.	130.0	.90	.81	.57	.08	.20	-.199	.021	.057
87	8	EX3	49.3	13.39	299.	278.0	53.	127.0	.80	.70	.55	.06	.20	-.186	.012	.049
88	8	BX4	47.6	14.88	304.	277.5	55.	127.2	.94	.76	.53	.10	.22	-.216	.027	.063
89	8	BX5	47.8	12.87	289.	277.2	55.	130.0	.75	.66	.54	.10	.22	-.185	.031	.065
90	8	BX6	46.7	11.74	285.	277.5	57.	129.4	.84	.78	.51	.08	.20	-.148	.017	.052
91	8	BX7	48.7	12.41	299.	277.9	52.	128.8	.75	.74	.49	.06	.20	-.121	.012	.045
92	8	BX8	49.0	14.62	304	277.5	55.	128.1	.90	.77	.57	.10	.23	-.231	.029	.066

Appendix 6 (Continued)

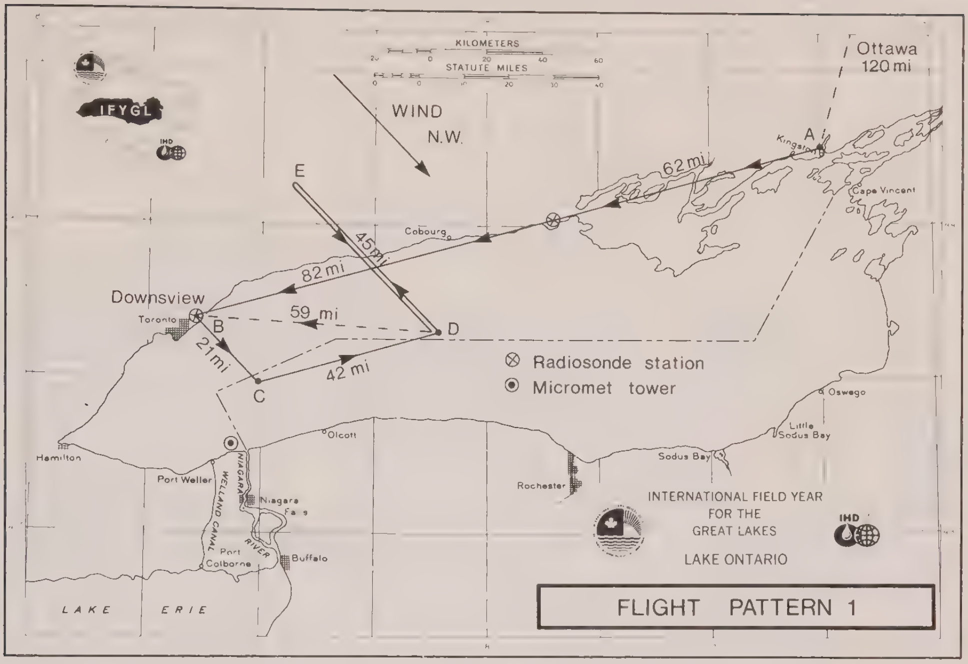


Figure 12. On legs indicated by dashes, no data to be collected. Legs B-C, E-D, D-E parallel to wind; A-B, C-D parallel to shore.

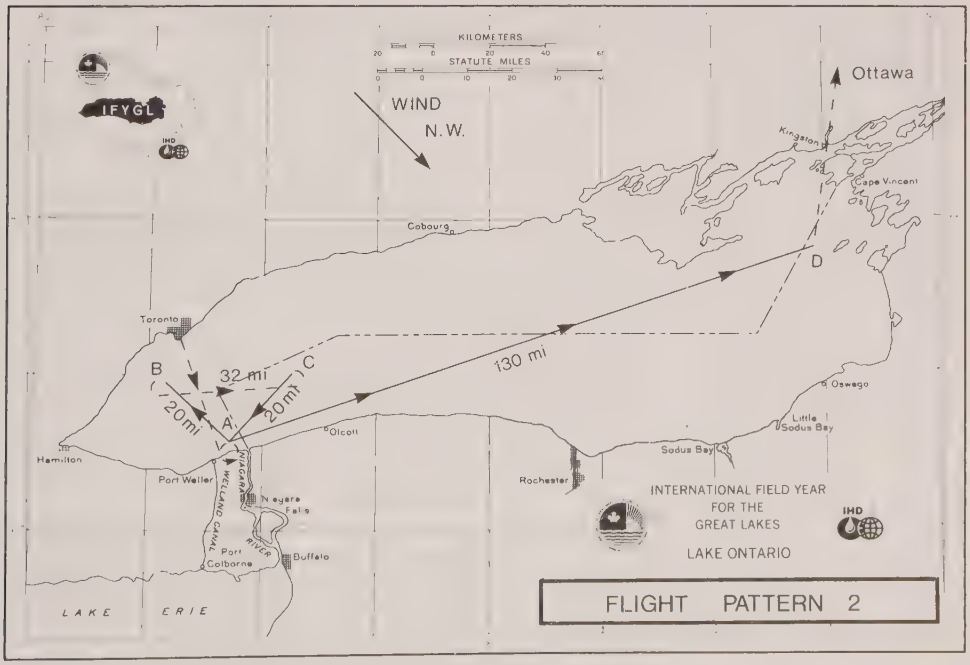
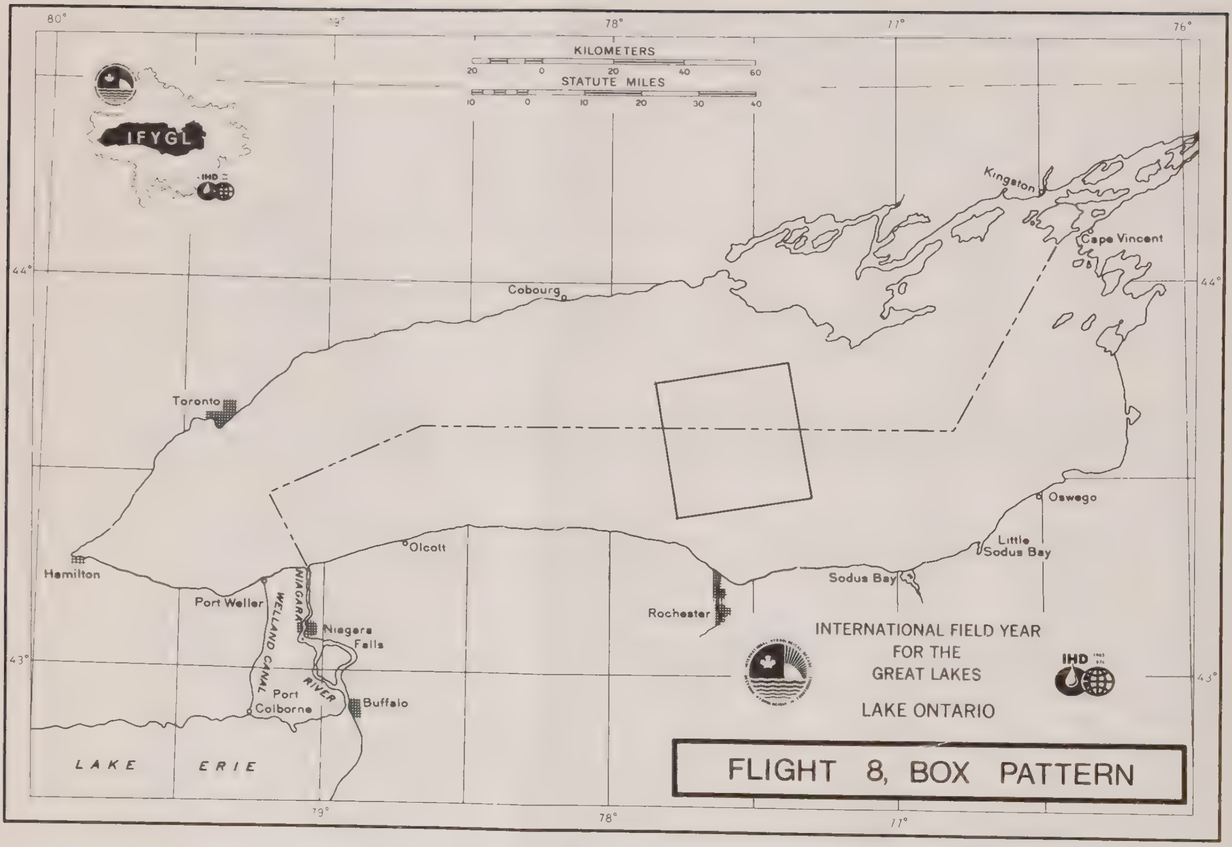


Figure 13. Leg A-B along wind; C-A perpendicular to wind; A-D parallel to shore. Triangular pattern A-B-C to be repeated at 50', 200', 500', 1000', 8000'. A-D at 500'.

Appendix 6 (Continued)



Appendix 6 (Continued)

Investigator: G. A. McBean

Platform: NAE-T-33 - turbulence data

May	13	14	15	16	17	18	19	20	21	22	23	24	25	26

June	12	13	14	15	16	17	18	19	20	21	22	23	24	25

August	11	12	13	14	15	16	17	18	19	20	21	22	23	24

October	2	3	4	5	6	7	8 X	9 X	10	11	12 X	13	14	15 X

November	12	13	14	15	16	17	18	19	20	21	22	23	24	25

December	13 X

UNITED STATES

Editors	Fred Jenkins and May Laughrun
Editorial assistance and typing	Patricia Mentzer

COMMENTS BY THE U.S. DIRECTOR

This issue covers IFYGL activities from April 1 to June 30, 1973 (see fig. 1). Some reports on events in July and August are included.

The major emphasis during this quarter was on data management. A major accomplishment was achieved by the team from the IFYGL Project Office, the Lake Survey Center, and the Center for Experiment Design and Data Analysis (CEDDA), who has developed and tested processing procedures for the Physical Data Collection System (PDCS), consisting of buoys, towers, and automatic meteorological stations. After an industrious 8 months, production of the PDCS Provisional Data Base is beginning, and is expected to proceed according to the schedule shown in figure 2. The processing procedures used are described in a later section of this Bulletin.

Considerable progress has been made in processing data from the U.S. ships *Researcher* and *Advance II* for the Provisional Data Base. Rawinsonde data processing by the CEDDA/USAF team is also proceeding successfully. Information received from Brad Bean indicates that the RFF aircraft data processing should be completed during the first quarter of 1974. Jim Wilson's work on precipitation, for which he is processing weather radar data in combination with other data types, should be finished by June 1974. Water-sample chemical analyses have been completed at the EPA Rochester Laboratory and will be entered into STORET shortly.

The above data management efforts are not an end in themselves. The obvious reason is to provide users with data. But for us to do so requires initiative on the part of those interested in receiving data. You are encouraged to file data requests and personally contact the U.S. Data Manager, Dave Drury, D2x1, CEDDA, EDS, NOAA, Page Bldg. 2, Washington, D.C. 20235. Despite a heavy workload, we will do our best to meet your data needs.

Attention of all United States and Canadian IFYGL scientists is directed to the Second IFYGL Symposium planned with IAGLR at McMaster University, August 12 to 14, 1974. Manuscripts must be sent in by May 1974. IAGLR has agreed in principle to print a Proceedings in two parts, one of which will contain the IFYGL papers. You are encouraged to participate, as indicated in the letter reproduced on p. 38.

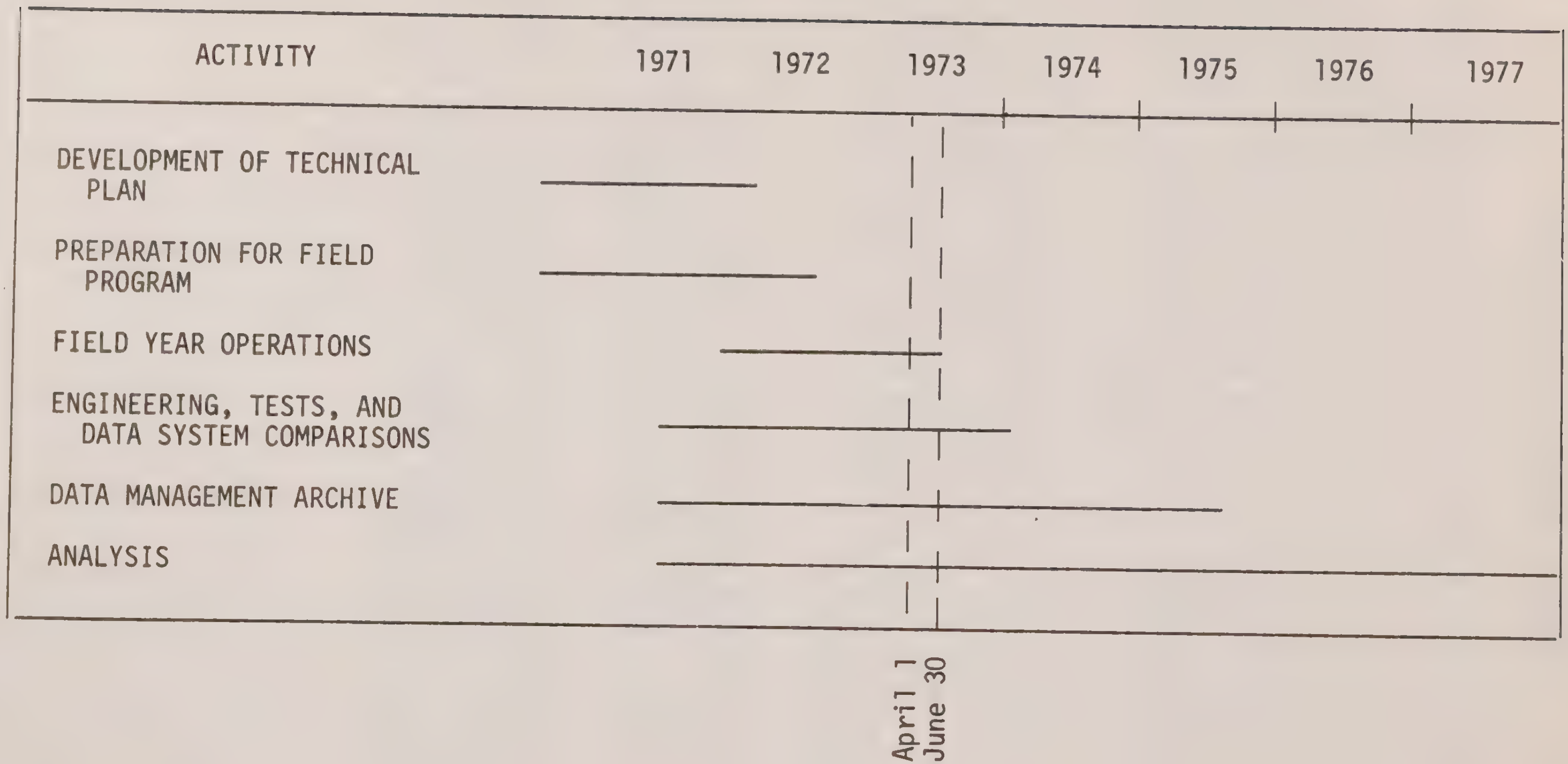


Figure 1. U.S. IFYGL schedule.

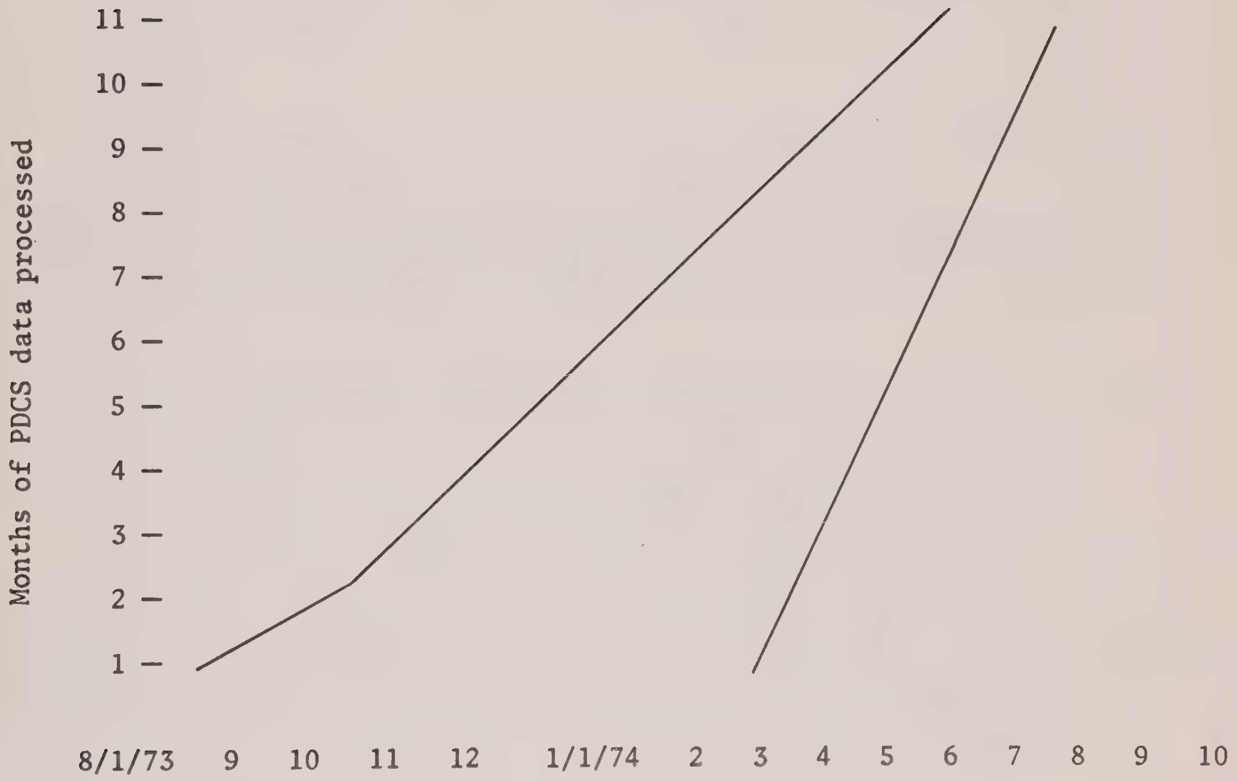


Figure 2. Processing schedule for PDCS Data Base.

INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

IFYGL

IHD

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AES File: 5964-31-3 (ACHC)

ATMOSPHERIC ENVIRONMENT SERVICE
4905 Dufferin Street
DOWNSVIEW, Ontario M3H 5T4
June 27, 1973

IFYGL Principal Investigators

Reporting of IFYGL Results

Arrangements have been made with the International Association for Great Lakes Research that a full three days of scientific sessions at the next Annual Conference of IAGLR will be devoted to papers arising from the IFYGL. There will likely be two or three other sessions running concurrently with the special IFYGL sessions.

The conference will be held at McMaster University, Hamilton, Ontario, August 12-14, 1974, and will be co-hosted by the University and the Canada Centre for Inland Waters. The conference will be followed immediately by an event sponsored by S.I.L. (International Society of Limnology) which is holding its triennial Congress in Winnipeg, August 26-30. This event at CCIW will be a pre-Congress special symposium (August 15) on Great Lakes limnology, consisting of six invited papers, and will be open to IAGLR conference participants as well as to those participating in SIL pre-Congress Tours.

You are encouraged to complete your IFYGL projects to a report presentation stage for this conference. Manuscripts will be required by May, 1974. The IFYGL Joint Management Team will assist the Conference Program Committee in selecting papers for presentation. We are hoping to arrange with IAGLR for joint publication of a special IFYGL volume of papers given at this conference.

Your cooperation and participation in this important event would be greatly appreciated.

T. L. Richards
T.L. Richards
Canadian Co-chairman
IFYGL Joint Management Team

E. J. Aubert
E.J. Aubert
U.S. Co-chairman
IFYGL Joint Management Team

c.c. IFYGL Joint Management Team
IFYGL Steering Committee

Jointly sponsored by Canadian and U.S. National Committees for International Hydrological Decade

U.S. SCIENTIFIC PROGRAM

Progress on the U.S. IFYGL tasks for the period April 1 through June 30, 1973, is presented below. Project/Panel status reports follow the task reports.

Tasks

1. *Phosphorus Release and Uptake by Lake Ontario Sediments*

Principal Investigators: D.E. Armstrong and R.F. Harris - University of Wisconsin

Analytical and experimental goals met following the second sampling trip include measurement of total P, total inorganic P, organic P, interstitial inorganic P, NH_4Cl-P, NaOH-P, CDB-P, HCl-P, and the P sorption and desorption characteristics of the sediment. The sediment samples were obtained on the *Researcher* between November 6 and 9, 1972, at stations 52, 83, 92, 75, 76, 62, 60, 45, 34, 10, and 30.

Data were collected for comparing squeezing and centrifuge-filtration techniques of obtaining interstitial water and their applicability for in situ separations of interstitial water for inorganic P analysis.

Data compilation and evaluation for publication was begun.

Analysis of the sediments has not presented any major problems. However, recent data have indicated a need for more frequent sampling to avoid changes occurring from long-term sediment storage. Storage is a problem particularly for interstitial inorganic P analysis where immediate separation of the interstitial water from the sediment is probably necessary.

2. *Net Radiation*

Principal Investigator: M.A. Atwater - CEM

The basic data set for the entire Field Year has been fully coded and stored on magnetic tape. Delays in receipt of data have slowed down computations of radiation fluxes for the full year for the 30-grid-point array, but work is proceeding. Details concerning the computations are given in the Interim Report of April 1973, "The Radiation Budget of Lake Ontario Including Cloud Coverage, Preliminary Results," by M.A. Atwater, J.T. Ball, and P.S. Brown, Jr. Weekly radiation values in that report can be updated for 50 weeks of the Field Year by means of Version A (all available documentation). Weekly spatially averaged radiation fluxes are

presented in figure 3. The weekly spatially averaged net radiation is shown in figure 4. Figure 5 shows observed and computed solar radiation fluxes at Brockport, N.Y.

The solar radiation model is described in detail in "Numerical Computations of the Latitudinal Variation of Solar Radiation for an Atmosphere of Varying Opacity," by M.A. Atwater and P.S. Brown, Jr. This paper was partly supported by the Atmospheric Sciences Section of the National Science Foundation and has been submitted for publication.

3. *RFF/DC-6 Boundary Layer Fluxes*

Principal Investigator: B.R. Bean - ERL/NOAA

No report.

4. *Nitrogen Fixation*

Principal Investigator: R. Burris - University of Wisconsin

No report.

5. *Profile Mast and Tower Program*

Principal Investigator: J.A. Businger - University of Washington

We have analyzed the mean profiles of wind, temperature, and humidity for selected periods and are also looking at the eddy fluxes for these periods. This has required development of techniques to make corrections for any misalignment of the sonic sensors with respect to the mean wind direction. For the selected periods, we will first compare the fluxes of momentum, heat, and moisture obtained from both the mean profile and eddy correlation measurements. Satisfactory agreement between the two methods will provide a check on our data reduction and analysis procedures We will then begin analyzing the remaining data.

6. *Status of Lake Ontario Fish Populations*

Principal Investigator: J.F. Carr - Great Lakes Fisheries Laboratory

No report.

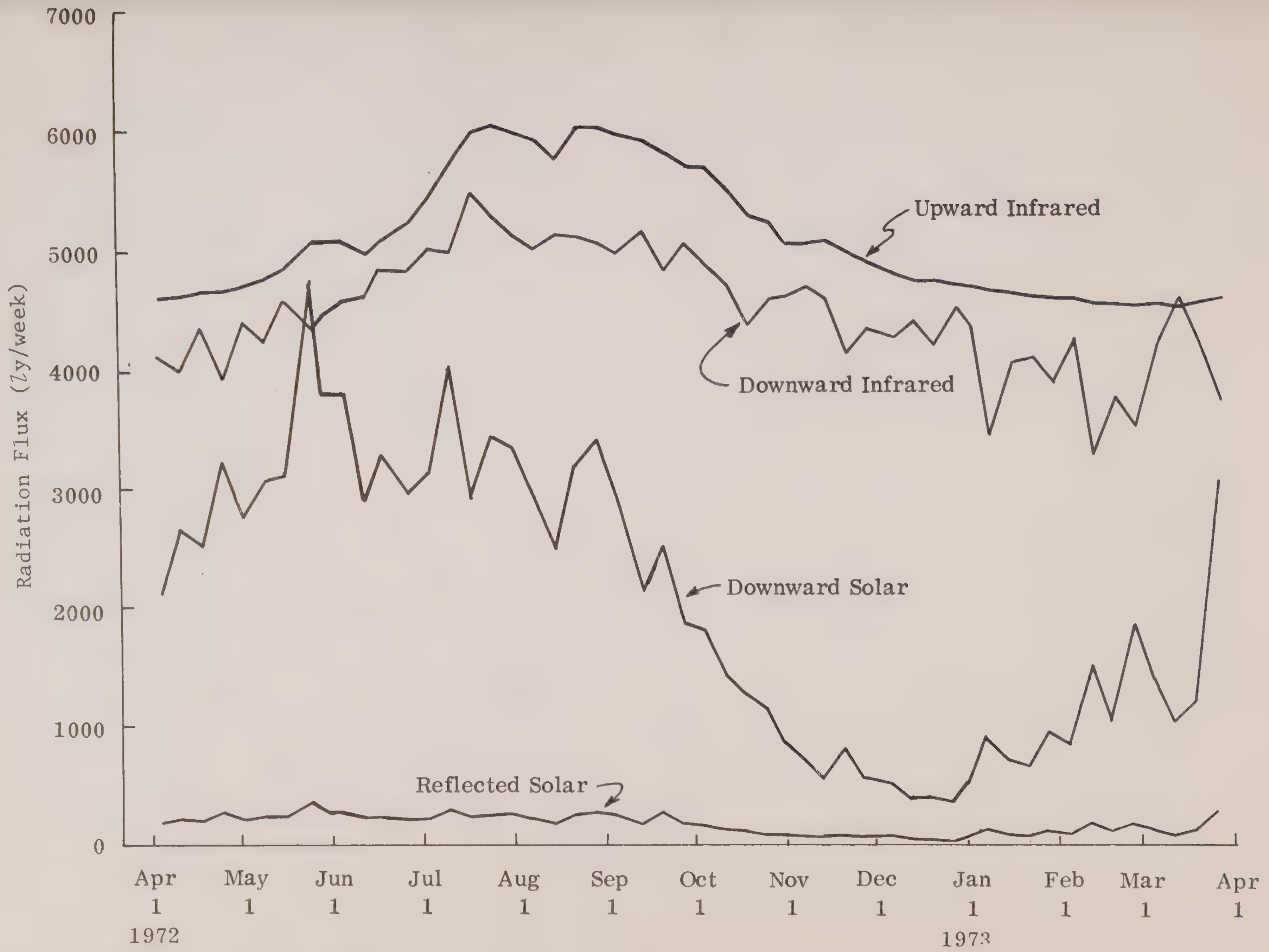

Figure 3. Weekly, spatially averaged radiation fluxes for Lake Ontario.

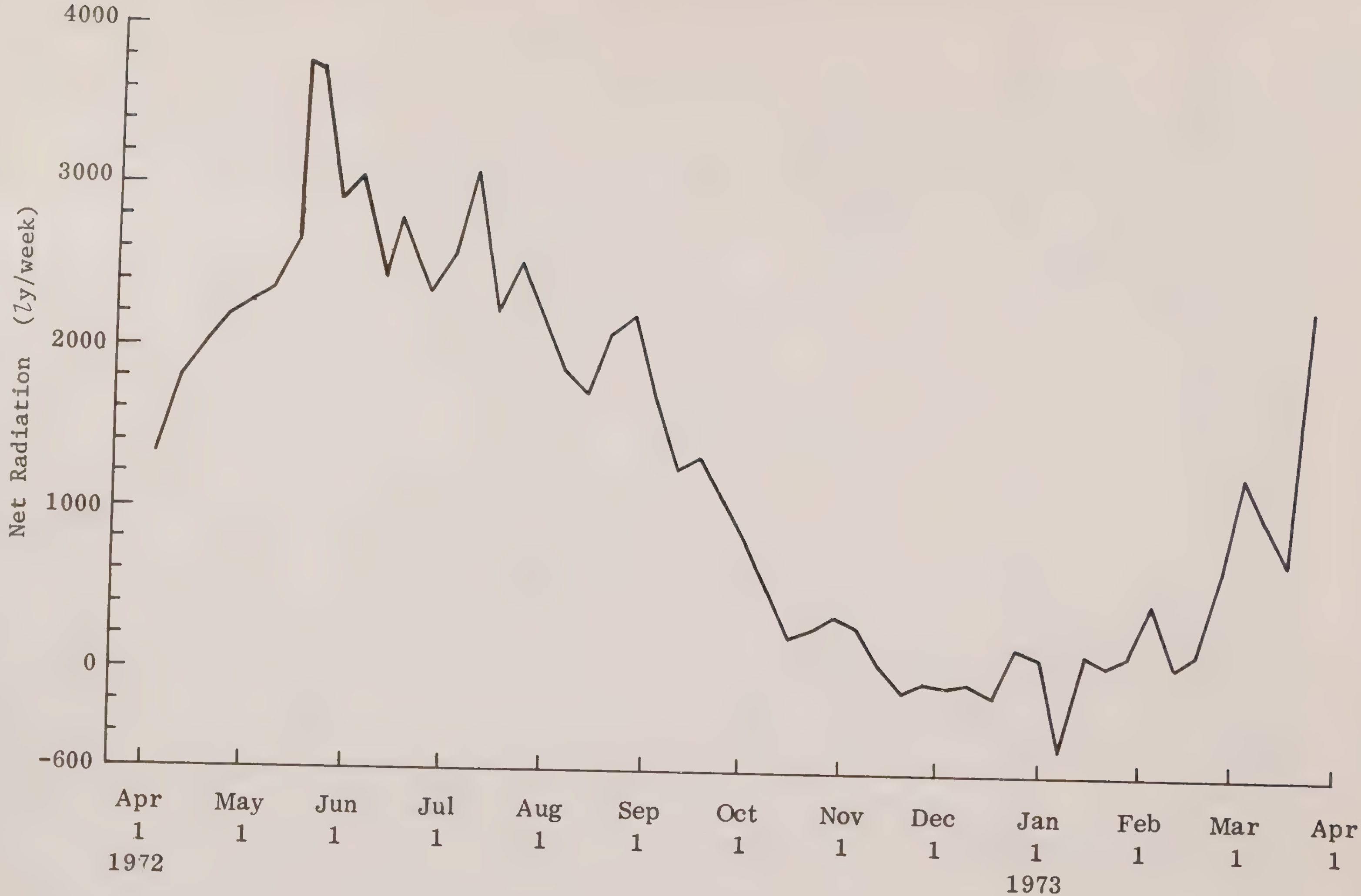

Figure 4. Weekly, spatially averaged net radiation flux for Lake Ontario.

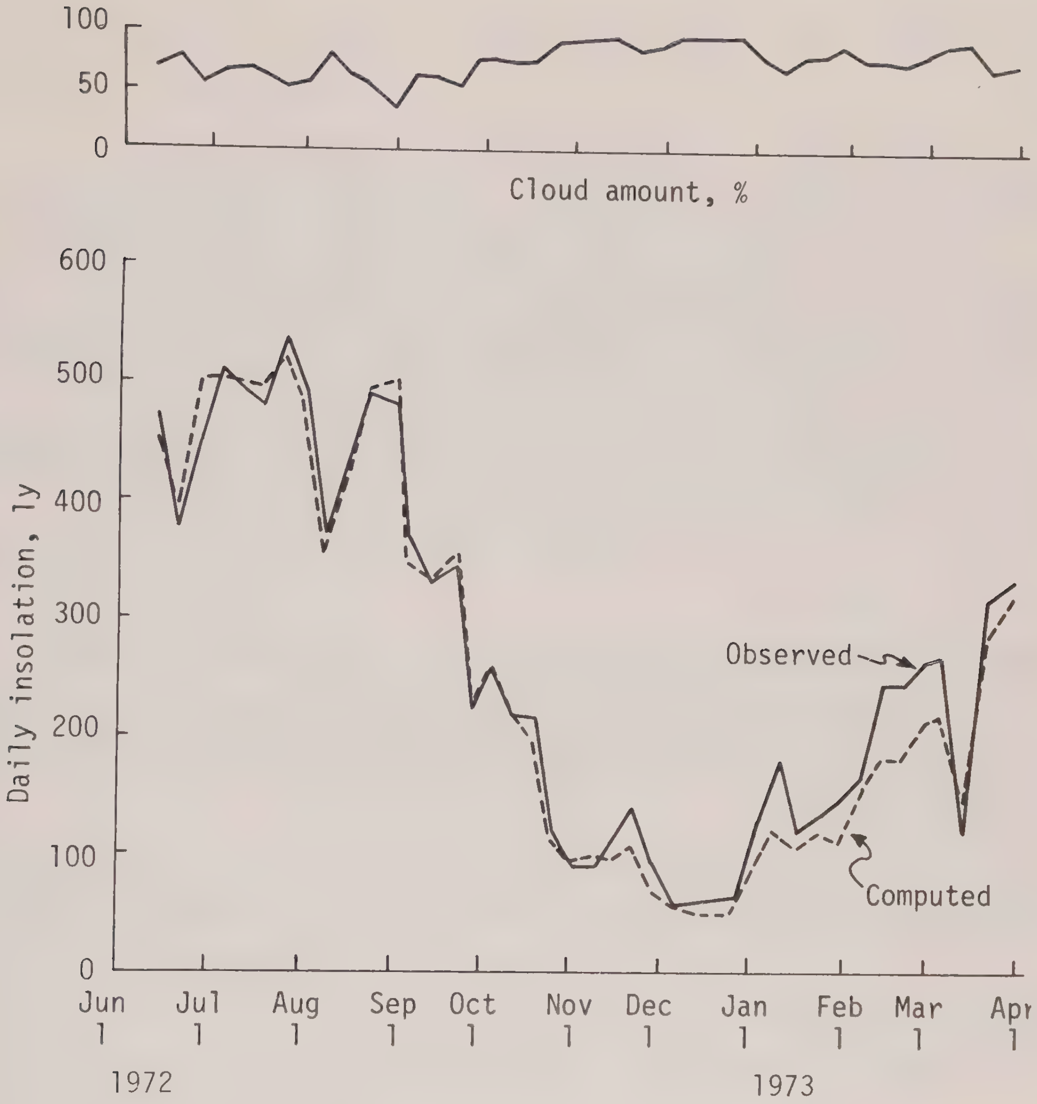

Figure 5. Weekly averaged cloud cover and weekly averaged daily observed and computed insolation for Brockport, N.Y.

7. *Material Balance of Lake Ontario*

Principal Investigator: D.J. Casey - EPA

No report.

8. *Runoff*

Principal Investigator: L.T. Schutze - U.S. Army Corps of Engineers

First-cut estimates of monthly runoff from the United States basin were derived for February and March 1973. Corresponding runoffs from the Canadian basin were not completed. We plan to continue making first-cut estimates of monthly runoff from these basins until agreement is reached on a method of extrapolating gaged data in each of the two countries.

No information has been received on discharge measurements at the mouth of important tributaries to verify methods of extrapolating gaged runoff over ungaged areas.

9. *Evaporation (Lake-Land)*

Principal Investigator: L.T. Schutze - U.S. Army Corps of Engineers

No progress made due to manpower shortage. Plans are to continue preparing first-cut estimates of monthly evaporation as provisional data become available, and to refine estimates when data from other investigators are received.

10. *Simulation Studies and Analyses Associated With the Terrestrial Water Balance*

Principal Investigator: B.G. DeCooke - U.S. Army Corps of Engineers

Activity has not begun.

11. *Land Precipitation Data Analysis*

Principal Investigators: L.T. Schutze and R. Wilshaw - U.S. Army Corps of Engineers

No progress made because of manpower shortage. Study of estimating methods will be continued during the next quarter. When a method has been selected, precipitation for short periods will be computed and compared with results obtained by other investigators.

12. *Transport Processes Within the Rochester Embayment of Lake Ontario*

Principal Investigators: W.H. Diment, G.F. Bonham-Carter,[1] and J.H. Thomas[1] - University of Rochester

Films from four current meters retrieved from the lake last fall have been digitized, and the results partly analyzed. Three additional meters have been retrieved.

Last year's results from the synoptic grid stations (temperature, electrical conductivity, beam transmittance, pH, dissolved oxygen, and chloride) have been digitized, and analysis has begun.

Modeling efforts are proceeding in parallel with continued data gathering. We have predicted the steady-state wind-driven circulation for Lake Ontario as a whole, and the Rochester embayment in particular, for winter conditions. We have investigated the sensitivity of the same model to changes in the geometry of the lake basin, and to spatially variable wind stress. A theory for shallow-lake circulation with variable eddy viscosity has been developed. We are working on a two-layer, vertically integrated model of Lake Ontario and the Rochester embayment, in collaboration with P. Katz and A. Kizlauskas from the University of Illinois.

We have collaborated with R.V. Thomann from Manhattan College, who is developing a biological and chemical model for Lake Ontario. We have supplied him with our model predictions (complete three-dimensional circulation for any wind conditions) on magnetic tape. He will use these data as input for his model.

We are also collaborating with Monroe County Health Department on a detailed study of water quality on Ontario Beach and are attempting to predict water quality as a function of wind history. Hourly samples from two stations off the beach are analyzed biologically and chemically, and wind data are recorded every 10 min.

Two reports on de-icing salts were prepared in connection with another project (NOAA Sea Grant GH-106). These may be of interest to those studying materials balance in Lake Ontario.

Without the aid of larger vessels and DECCA navigation, retrieval of the current meters is a more difficult operation than anticipated. We have had some success with a 27-ft cruiser provided by EPA and used in conjunction with our Boston *Whaler*, but 13 of the 20 meters remained in the lake as of July 24, 1973. Funds are short, and, once the size of the problem can be more fully assessed, we shall seek additional support.

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[1] Added as Principal Investigators on this task.

13. *Soil Moisture and Snow Hydrology*

Principal Investigator: W.N. Embree - U.S. Geological Survey

Work continues on the problem of computing monthly changes in soil moisture based on the neutron-log data. An initial determination has been made, but the results, and possibly the method of analysis, need further study.

Methods of analysis are being formulated pertaining to the use of soil moisture and snow data in predicting runoff. For such prediction, a model will be developed that should be improved by the addition of soil-moisture and/or snow data for the Black River basin.

14. *Boundary Layer Structure and Mesoscale Circulation*

Principal Investigator: M.A. Estoque - University of Miami

Analysis has been temporarily discontinued until rawinsonde, radar, aircraft, and surface data from other projects can be obtained. Computer programs for integrating a two-dimensional and a three-dimensional model are being written. Our effort during the next quarter will be concentrated on theoretical modeling. We will test our computer programs at the NCAR Computing Facility.

15. *Mesoscale Simulation Studies*

Principal Investigator: M.A. Estoque - University of Miami

No report.

16. *Lake Level Transfer Across Large Lake*

Principal Investigator: C.B. Felscher - LSC/NOAA

Several alternate methods were identified for isolating and determining the probable effect of wind, barometric pressure, and water and air temperatures on the slope of the surface of Lake Ontario. Analysis of the feasibility of these methods was begun.

17. *Nearshore Ice Formation, Growth, and Decay*

Principal Investigator: A. Pavlak - General Electric Company

Completion date for data reduction has been extended from June 30, 1973, to July 31, 1973, as a result of illness. Analysis is proceeding along the revised schedule.

18. *Advection Term - Energy Balance*

Principal Investigator: J. Grumblatt - LSC/NOAA

No report.

19. *Occurrence and Transport of Nutrients and Hazardous Polluting Substances in the Genesee River Basin*

Principal Investigator: L.J. Hetling - New York State Department of Environmental Conservation

Regular water quality network stations:

The biweekly stream sampling program is continuing on schedule and will continue through October 18. Laboratory analyses of the first 10 months of data have been completed and the data are being checked for accuracy.

In April a third set of samples was collected for pesticide analysis, and a third set of samples for analysis of mercury, cadmium, lead, copper, nickel, manganese, chromium, and fluorides was collected in May. Two sets of sediment samples have been taken and will be analyzed for phosphorus, iron, magnesium, aluminum, and calcium. Sediment, pesticides, and heavy metals will be sampled in August and October.

Stream system nutrient uptake:

Sampling on three streams (Fish Creek, Holcomb; Spring Brook, Lima; and Avon Creek, East Avon) began on May 8, 1973, and has continued on a biweekly basis. This routine sampling provides 25 stream and sediment samples and 3 wastewater samples. Plankton and macrophyte samples are taken at selected stations along each stream. The fourth stream (Mud Creek, Victor) was dropped because the ratio of wastewater flow to streamflow was too low.

An intensive sampling program to be undertaken in early August will provide for daily samples for 5 days on each of the three streams. The sampling will include the addition of a number of stations so that certain inputs to the stream (particularly tributaries and field drains) that are not normally monitored can be adequately checked. This will give, for the three streams, a total of 42 stream and sediment samples, 3 wastewater samples and several plankton and macrophyte samples. These will be analyzed as described earlier. After the intensive sampling period, regular biweekly sampling will be resumed on August 28, 1973, and continue through October 25, 1973.

20. *Boundary Layer Flux Synthesis*

Principal Investigator: J.A. Almazan - CEDDA/NOAA

The United States meteorological buoy wind data were validated, based on a lake-land breeze analysis done by Jason Ching of CEDDA. Wind data from the United States and Canadian buoys for July 8 to 21, 1972, were used to compute diurnal variations of the north-south wind component and a similar component normal to the northern and southern shores of Lake Ontario. The lake was divided into "northern, middle, and southern" regions. The results show that a pronounced lake-land circulation was superimposed on a diurnal variation of larger scale. Analysis of the temperature field in the lake-land circulation was begun.

21. *Hazardous Material Flow*

Principal Investigator: T. Davies - EPA

No report.

22. *Remote Measurement of Chlorophyll With Lidar Fluorescent System*

Principal Investigator: H.H. Kim - NASA

No report.

23. *Inflow/Outflow Term - Terrestrial Water Budget*

Principal Investigator: I.M. Korgigian - U.S. Army Corps of Engineers

The final report on the Lake Ontario outflow measurements has been submitted to the U.S. IFYGL Data Center. The task is completed.

24. *Use of an Unsteady-State Flow Model To Compute Continuous Flow*

Principal Investigator: I.M. Korgigian - U.S. Army Corps of Engineers

Work has been delayed due to lack of manpower. Plans are to measure discharge simultaneously at two hydraulic sections on the St. Clair River to provide basic data for developing the unsteady-state flow model. Its proximity to Detroit makes this river more advantageous to measure than the Niagara or St. Lawrence. The results will be used to construct the model, which, with account taken of past measurements on the St. Lawrence, will then be adapted for computing Lake Ontario's outflow.

25. *Radiant Power, Temperature, and Water Vapor Profiles Over Lake Ontario*

Principal Investigator: P.M. Kuhn - ERL/NOAA

Task completed.

26. *Algal Nutrient Availability and Limitation in Lake Ontario*

Principal Investigators: G.F. Lee[2], N. Sridharan, and W. Cowen - University of Wisconsin

Sampling trips to Lake Ontario tributaries were made on April 6, 7, and 30, May 1, 27, and 28, and June 15, 16, and 17, 1973. Open-water lake samples were collected by CCIW from April 26 to 29, and on June 15 and were transported to Madison.

Except for long-term nitrogen and phosphorus availability studies, analytical work for the quarter was completed. In nutrient enrichment experiments with Lake Ontario water, absorbance, fluorescence, and carbon fixation rates were used to measure growth stimulation of the natural phytoplankton. *Selenastrum* growth assays were used to estimate percent of phosphorus in particulate and soluble forms in New York tributaries. Rainfall and bulk precipitation samples received from D.J. Casey, EPA, Rochester, were also subjected to *Selenastrum* growth assays.

Some of the problems in assaying particulate matter in dilute runoff samples have been overcome by use of new methods. New procedures, such as high-speed centrifugation and/or ultrafiltration may also be required to evaluate phosphorus characteristics of the rainfall samples.

Future plans include data compilation and evaluation. Very limited laboratory work will include rainwater analyses and growth assays.

27. *Wave Studies*

Principal Investigator: P.C. Liu - LSC/NOAA

No report.

28. *Cloud Climatology*

Principal Investigator: W.A. Lyons - University of Wisconsin

No report.

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[2] Now affiliated with Texas A & M University.

29. *Zooplankton Production in Lake Ontario as Influenced by Environmental Perturbations*

Principal Investigator: D.C. McNaught - State University of New York at Albany

No report.

30. *Change in Lake Storage Term - Terrestrial Water Budget*

Principal Investigator: R. Wilshaw - U.S. Army Corps of Engineers

No progress during this quarter. Plans call for computer programming and data processing to be completed by the end of 1973. Results should be available shortly thereafter.

31. *Soil Moisture*

Principal Investigator: L.T. Schutze - U.S. Army Corps of Engineers

The investigation has not started.

Lack of manpower and of data from other investigators on precipitation, evaporation, and runoff continues to delay the start of this task. When work is begun, water storage on and below the ground surface will be determined as a single storage factor from the land water balance equation.

32. *Testing of COE (Corps of Engineers) Lake Levels Model*

Principal Investigator: E. Megerian - U.S. Army Corps of Engineers

No report.

33. *Nearshore Study of Eastern Lake Ontario*

Principal Investigator: R.B. Moore - State University of New York at Oswego

No report.

34. *Internal Waves - Transects Program - Interpretation of Whole-Basin Oscillations*

Principal Investigator: C.H. Mortimer - University of Wisconsin, Milwaukee

During the period April 1 to June 30, we began to apply some of the theories for whole-basin internal oscillations, principally those put forth by the Principal Investigator, to the interpretation of temperature vs. depth information collected during our three cruises aboard the *Researcher* and *Advance II*. Isotherm depth fluctuations are observed on almost all space and time scales from short, high-frequency waves (below the resolution of our instruments and sampling program) through whole-basin "adjustments" lasting several days. During the August 7 to 11 cruise, the Lake Ontario region was hit with a particularly violent wind storm. Cross sections from this period show a considerable amount of activity. Prominent in the midlake cross sections are a series of waves or "troughs" propagating regularly northward from the downwelling on the south shore. A preliminary analysis of these features was included in a presentation at the 1973 IAGLR Conference in Huron, Ohio.

Work is progressing on the reduction of the last bits of temperature/depth data. Tying loose ends together seems to be more time-consuming than ploughing through the main body of the data. It was recently discovered that during the July 24 to 28 cruise the temperature calibration for the undulating fish had shifted around several times. This meant determining new calibrations and rerunning the isotherm depth finding programs for about ten transects. It has also lately occurred to us that additional information can be squeezed out of the undulator records. It may be possible in some instances to map the temperature structure much nearer the surface than we are now doing. It also may be possible, from inspection of time series plots of temperature, to filter out high-frequency internal waves and thereby determine mean thermocline depths much more accurately.

The plan for the next quarter is to (finally) finish up the undulator data reduction and to produce a report on all data collected. This will involve processing one field tape (four transects) that now has a missing (unrecorded) track. The idea is to fill in the missing bit so as to restore or preserve the proper parity. In addition we intend to press on with our interpretation of the results. As a by-product of another research project we now have at our disposal a numerical technique to predict the characteristics of low-frequency internal waves propagating along a long channel of rather arbitrary shape. It shows the Stokesian edgewaves and topographic Rossby waves which were neglected by Mortimer in his treatment of a channel with a flat bottom.

35. Pontoporeia affinis *and Other Benthos in Lake Ontario*

Principal Investigator: S.C. Mosley - University of Michigan

No report.

36. *Pan Evaporation Project*

Principal Investigator: T.J. Nordenson[3] - NWS/NOAA

Class A evaporation pans were reinstalled on schedule at all evaporation stations. Data have been recorded from April through June 1973, after which the stations were discontinued. Dew-point and radiation data will be added when they arrive. Computation is proceeding of shallow-lake evaporation at the three Canadian stations for the winter months. Analysis of the United States data is behind schedule because dew-point and radiation data have not been received from the collocated IFYGL meteorological stations.

When the necessary dew-point and radiation data become available, shallow-lake evaporation computations will be made and, upon receipt of change in energy storage and advected energy data, corrections applied to obtain Lake Ontario evaporation estimates.

An aerodynamic equation will be used to substitute for dew-point data for the months of April, May, and June 1973 when the meteorological stations were no longer in operation. Development of this equation depends upon availability of dew-point data for the period April 1972 to March 1973.

37. *Simulation Studies and Other Analyses Associated With U.S. Water Movements Projects*

Principal Investigators: J.P. Pandolfo and C.A. Jacobs - CEM

A report entitled "The Numerical Simulation of the Response of Lake Ontario to the Passage of a Typical March Cold Front" has been completed and mailed to the IFYGL Project Office. With some minor modification to the one-dimensional air/lake boundary layer model, the specification of any or all of the atmospheric dependent variables -- wind (u, v components), temperature (T_A), and humidity (q) -- as a function of height and time was allowed for the simulation experiment. Of primary concern was the detailed time and space (vertical) structure of the currents, water temperature, sensible and latent heat fluxes, and stresses across the air water interface and

[3] C. Hoffeditz, NWS/NOAA, will become Principal Investigator on this task as of July 1, 1973.

within the water column. The results were compared with a previous climatological simulation of the lake (see "Numerical Simulations of Lake Ontario with a One-dimensional Air/Lake Model" by J.P. Pandolfo and C.A. Jacobs). The report contains much useful information, not obtainable from field experiments, for other IFYGL investigators concerned with the dynamic, thermodynamic, chemical, and biological regimes of the lake during the winter months. The model results reveal some of the first physically consistent estimates for March of time and space variability, orders of magnitude, and ranges of the vertical exchange coefficients for eddy viscosity and conductivity-diffusivity, sensible heat flux and stress within the water layer, and certain components of the interface heat budget.

38. *Structure of Turbulence*

Principal Investigator: H.A. Panofsky - Pennsylvania State University

Analysis was continued of coherence and phase relations among wind-speed fluctuations measured at Niagara Bar in August 1972. Study of several additional runs showed small coherences even when the wind was lined up with the masts. The reason is believed to be that, in contrast to earlier runs, the air temperature exceeded the water temperature (stable stratification). Phase analysis for another run confirmed Taylor's hypothesis extraordinarily well. Additional runs will be analyzed with emphasis on zero-Richardson number conditions. A hypothesis dealing with diagonal coherence (2 m at one tower and 7 m at another) will be tested more fully.

Continued analysis of buoy wind records failed to show any coherence among adjacent buoys. At several buoys, however, interesting spectral peaks for speed and direction were found for periods close to an hour, with wind speed and direction in quadrature suggesting longitudinal vortices. So far, wind directions are not known well enough to judge exactly the relation between coherence and angle between wind direction and the anemometers. Better wind-direction data will be available shortly from CCIW. The buoy analysis will be written up shortly.

Results from this task will be discussed at the IAMAP Assembly, Melbourne, Australia.

39. *Airborne Snow Reconnaissance*

Principal Investigator: E.L. Peck - NWS/NOAA

The following interim reports were published in May 1973:

Interim Report # 3, "Soil Moisture Measurements Made at Calibration Lines on February 28-March 1, March 9, and March 28, 1973."

Overlooked in the previous quarterly report was a brief summary of plans and current progress provided on March 28, 1973, to B.G. DeCooke, Cochairman of the Terrestrial Water Balance Panel.

Arrangements have been to obtain additional snow data from the special collection program conducted by the University of New York in support of the radar snow measurement project. A paper on "Lake Ontario Snowfall Observational Network for Calibrating Radar Measurements" is to be presented at an international symposium on snow and ice to be held in Monterey, Calif., from December 2 to 6, 1973. The paper is being prepared in collaboration with J. Wilson of The Center for Environment and Man.

Further processing and analysis of aircraft data will include the mission flown on March 28, 1973. Ground survey data will also be incorporated into the analysis to provide final snow-water equivalent estimates along the aerial reconnaissance network. An interim report will contain a summary of the aerial radiation measurements. Analysis results will be given in a final task report.

40. *Optical Properties of Lake Ontario*

Principal Investigator: K.R. Piech - Calspan Corporation

As stated in IFYGL Bulletin No. 4, the objectives of this task are (a) measuring the optical properties of Lake Ontario, especially with reference to spatial and temporal characteristics and photic zone definition, (b) providing inputs to the lake heat budget and to chemical and biological studies, and (c) comparing and evaluating three techniques for optical turbidity measurements: Secchi disk, irradiance meter/transmissometer, and aerial photographic photometry.

Efforts to date have consisted of planning and completing data collection, and preliminary data reduction (see tables 1 and 2). Preliminary data reduction is essentially complete, and all data have been entered into a format that facilitates temporal, areal, and intersensor comparisons required to meet the objectives outlined above. Analyses in terms of these objectives will begin during the next reporting period.

All ship data have been reduced to a graphical format. Preliminary analyses indicate reasonable consistency between transmissometer, irradiance meter and Secchi disk data, although the usual data scatter caused by variations in illumination and surface wave conditions is present.

Table 1. Surface optical measurements

Equipment	Measurement details	Data reduction
Transmissometer Hydro Products Model 612 used in one-meter configuration. Type 5 CdS photocell sensor; #328 lamp source. Manual readout of meter display.	Maximum depth 125 ft. Transmissometer readings to maximum depth, irradiance readings to 1-percent level.	Currently into graphical format.
Irradiance Meter Modified Hydro Products Model 620. Upwelling, downwelling and gimballed deck sensor. PIN 6D photodetector with stacked Kodak infrared cutoff filters Nos. 301 and 305. (30-percent wavelength cutoff on No. 305 at 6400 Å). Readings made with Wratten 92 (red), 93 (green), and 94 (blue) gelatin filters. Manual readout of meter display.	Transmissometer in vertical mode suspended 3 ft below irradiance meter.	
	Short station dwell time measurements: transmissometer, irradiance meter Wratten 93 only.	
	Long station dwell time measurements: transmissometer, irradiance meter with all filters.	
	Secchi disk reading recorded from *Researcher* measurement.	
	Cruise beginning dates: May 1, May 23, June 12, July 10, August 21, September 11, October 16, October 29, November 27. Cruise duration about 1 week.	
	Approximately 30 stations per cruise, during daylight hours only.	

Table 2. Aerial optical measurements

Equipment	Measurement details	Data reduction
Four Hasselblad 500 EL cameras with 80-mm lenses. Manual firing of cameras.	Altitude 10,000 ft.	Shadow densitometry for photometric calibration.
Two cameras unpolarized. Two with polarizing filters rotated by 45°.	Scale 1:40,000 (1.4 m side to side; 1.7 sq. mi per frame).	Lake densitometry for volume reflectance, attenuation coefficient, photic zone definition.
Ektachrome MS 2448 color film.	Piper Aztec C (no window until mission on November 17).	
Hernfeld sensitometer for color wedges. Wedge temperatures 5,500°K and 14,000°K. Twenty-one stop colloidal suspension M type carbon wedges.	Four north-south tracks, including Master Water Quality Stations 10, 22, 41 and 67.	
	Flight speed 150 kn.	
Densitometry with noncommercial stereoscope/microdensitometer; Macbeth macrodensitometer. All densitometric measurements through Wratten 92, 93, or 94 filters.	One frame of imagery every minute; at 20-s intervals every third minute. Shoreline imagery at track end points for photometric calibration. About 25 frames per track.	
	Flight dates: June 16, June 27, July 17, August 30, September 11, October 19, November 17. Approximate flight length 3+ hr.	
	Flight times about 1500 to 1900 GMT.	

Reduction of aerial data necessitates establishing the relationship between densities on the color film layers and lake reflectance. An initial step reduces film densities to relative sensor exposure through use of a step wedge.

In the calibration technique, analyses of scene shadow areas are used to establish the relationship between sensor radiance and ground reflectance. To put it briefly, a linear relationship exists between the radiance just inside and outside a shadow. The parameters of this relationship are related to the component of radiance due to atmospheric scattering or flare and to the ratio of sunlight to skylight irradiance. Thus, the relationship between sensor radiance and scene reflectance can be established by measuring sunlight and shadow radiance for a set of shadows and determining the parameters of the fit to the data set. The shadow calibration technique requires no atmospheric modeling (and consequent model parameter measurement); rather, the calibration proceeds entirely from the sensor record of shadow elements within the scene to determine the atmospheric component of radiance. As a result, a calibrated sensor record is obtained in which sensor response is directly proportional to scene reflectance.

A typical sunlight-shadow radiance plot for an end point of one of the lake tracks shows that the calibration parameters obtained from these end-point analyses appear to be very consistent. The atmospheric component of radiance obtained from the calibration parameters is usually on the order of 30 to 40 percent of the total radiance from the lake. Hence it is very important for this component of sensor radiance to be determined as accurately as possible if lake reflectances obtained from the aerial photography are to be used for optical characterization. Imagery across the lake has been reduced to relative radiance plots. Data from these plots, reduced to lake reflectance values, will be incorporated into the data matrix format described below.

To facilitate data comparison and analysis, all surface and aerial data are being incorporated into a matrix format that will allow rapid recall and display of temporal, areal, and intersensor comparisons. Sufficient capacity has been maintained in this formating to allow incorporation of other data of interest in optical analyses.

A more complete quarterly report containing plots of the optical data was submitted to the IFYGL Project Office. Scientists having need for samples of these data outputs should contact the Principal Investigator directly.

41. *Storage Term - Energy Balance Program*

Principal Investigator: A.P. Pinsak - LSC/NOAA

No report.

42. *Sensible and Latent Heat Flux*

Principal Investigator: A.P. Pinsak - LSC/NOAA

No report.

43. *Thermal Characteristics of Lake Ontario and Advection Within the Lake*

Principal Investigator: A.P. Pinsak - LSC/NOAA

No report.

44. *Oswego Harbor Studies*

Principal Investigator: G.L. Bell - LSC/NOAA

No report.

45. *Mapping of Standing Water and Terrain Conditions With Remote Sensor Data*

Principal Investigator: F.C. Polcyn - University of Michigan

No report.

46. *Remote Sensing Program for the Determination of* Cladophora *Distribution*

Principal Investigators: F.C. Polcyn and C.T. Wezernak - University of Michigan

No report.

47. *Remote Sensing Study of Suspended Inputs Into Lake Ontario*

Principal Investigators: F.C. Polcyn and C.T. Wezernak - University of Michigan

No report.

48. *Island-Land Precipitation Data Analysis*

Principal Investigator: F.H. Quinn - LSC/NOAA

Precipitation data have been collected continuously at the six Lake Ontario stations, except for some intermittent data caused by malfunction of four gages. Data tapes through May 1973 are being reduced. Data collection and reduction are on schedule.

49. *Lake Circulation, Including Internal Waves and Storm Surges*

Principal Investigator: D.B. Rao - University of Wisconsin, Milwaukee

No report.

50. *Atmospheric Water Balance*

Principal Investigator: E.M. Rasmusson - CEDDA/NOAA

Programming of the budget analyses scheme continued during the quarter. The software for fitting the basic measured quantities (u, v, T, q) as functions of latitude, longitude, pressure, and time is essentially complete.

Preliminary rawinsonde data are expected to become available during the next quarter. Using these data we will do the following:

(a) Compare observed values at the exact position of the observation, i.e., taking into account the drift of the balloon, with those obtained from the analyses procedure.

(b) Using values of measured parameters obtained from the analyzed fields, compare mean values at the actual position of the balloon with those directly over the observing stations.

(c) Compile a statistical summary of the actual position of the balloon relative to each station as a function of pressure.

These analyses are expected to provide data to improve the analysis scheme and to evaluate the importance of accounting for the drift of the balloon.

Software development during the next quarter will be concentrated on completion of the programming of the computations of the derived budget quantities from the coefficients of the orthogonal functions describing the basic fields.

51. *Evaporation Synthesis*

Principal Investigator: E.M. Rasmusson - CEDDA/NOAA

Work on this project is now awaiting data. These include (a) meteorological data from United States and Canadian buoys, (b) evaporation estimates from the Terrestrial Water Balance, and Heat Balance Panels, and (c) evaporation estimates from the Atmospheric Water Balance analyses.

52. *Ground-Water Flux and Storage*

Principal Investigator: E.C. Rhodehamel - U.S. Geological Survey

Collection of water level data has continued in order to provide information for studying the hydraulic properties and hydraulic nature of lake-front materials.

The computation procedures for determining the monthly changes in groundwater storage (ΔS) have been refined and a trial run has been made. Descriptions of the methods of analysis used in determining the groundwater flux and S values are being prepared. Plans call for continued processing and computation of data for ΔS values, and preparing data for submission to the IFYGL data bank.

53. *Spring Algal Blooms*

Principal Investigator: A. Robertson - IFYGL Project Office/NOAA

Analysis awaits the availability of data.

54. *Ice Studies for Storage Term - Energy Balance*

Principal Investigator: F.H. Quinn - LSC/NOAA

Data reduction has been completed. Instrument calibration factors have been determined and have been applied to the data, which are now being verified.

55. *Lagrangian Current Observations*

Principal Investigator: J.H. Saylor - LSC/NOAA

No report.

56. *Circulation of Lake Ontario*

Principal Investigator: J.H. Saylor - LSC/NOAA

No report.

57. *Phytoplankton Nutrient Bioassays in the Great Lakes*

Principal Investigator: C. Schelske - University of Michigan

No report.

58. *Runoff Term of Terrestrial Water Budget*

Principal Investigator: C.K. Schultz - U.S. Geological Survey

Values of the mean weekly flows for the Field Year have been computed and will soon be sent to the IFYGL Data Center. A report has been written. This completes work on this task.

59. *Coastal Chain Program*

Principal Investigator: J.T. Scott - State University of New York at Albany

The basic data report on the United States coastal chain program required correction for transport calculations and will be mailed in August. Canadian coastal chain data were received from G.T. Csanady and processing has begun. This includes computation of baroclinic geostrophic velocity and breakdown into along-shore and normal-to-shore components of velocity. The result will be a comparison of the five coastal chains for cross sections of temperature, along-shore velocity, and baroclinic geostrophic velocity for a variety of natural "events" that occurred during the three alerts. We are planning a joint report with Csanady on certain aspects of one of the interesting events of "quasi-steady" flow that occurred in July 1972. When all five coastal chain cross sections are examined simultaneously the flow patterns indicate the possible existence of a long baroclinic ("Kelvin") wave.

Perhaps the major problem with the coastal chain program is in the "filtering" of small-scale perturbations from the "steady" flow. We had hoped to have more measurements of continuous data from moored current meters, but our own measurements were spotty because we could not free the spare current meters from the regular chain program. We are obtaining continuous records for several anchored (tower) or moored meters from CEDDA and CCIW. This aspect of our task will be postponed until early 1974.

During the next 6 months emphasis will be given to the "coherence" study, in which we will examine all five coastal chain cross sections for specific wind-stress periods. We are preparing the cross-sectional diagrams for the entire data set, and for specific "events," each lasting for 5 to 10 days. Csanady will attempt to prepare maps of wind stress and some estimate of air-water temperature difference for the appropriate days.

We also intend to continue our analysis of transport components as described in the IFYGL Technical Plan. The calculations have been made, and preliminary comparison of means of actual velocity versus baroclinic geostrophic velocity will begin later in 1973.

60. *Analysis of Phytoplankton Composition and Abundance*

Principal Investigator: E.F. Stoermer - University of Michigan

No report.

61. *Clouds, Ice, and Surface Temperature*

Principal Investigator: A.E. Strong - NESS/NOAA

No report.

62. *Analysis and Model of the Impact of Discharges From the Niagara and Genesee Rivers on Nearshore Biology and Chemistry*

Principal Investigator: R.A. Sweeney - State University of New York at Buffalo

No report.

63. *NCAR/DRI - Buffalo Program*

Principal Investigator: J.W. Telford - Desert Research Institute, University of Nevada

No report.

64. *Mathematical Modeling of Eutrophication of Large Lakes*

Principal Investigator: R.V. Thomann - Manhattan College

The primary effort during the quarter was continued sensitivity analysis on the three-layered vertical model (LAKE 1). Preliminary verification runs were also made. The two main areas investigated

during these runs were the effect of vertical dispersion and the effect of phytoplankton settling velocity on the growth of phytoplankton. The vertical dispersion in LAKE 1 is time-variable to simulate the development of the thermocline. The effect of vertical dispersion was analyzed based on a range of values. This analysis revealed the effect mixing has on the magnitude and time location of the pulses in phytoplankton growth. The sensitivity of phytoplankton growth to phytoplankton settling velocities was also investigated. The effects of two different settling rates were determined.

Plans for the next quarter are to continue the sensitivity analysis and verification on LAKE 1.

65. Cladophora *Nutrient Bioassay*

Principal Investigators: G.F. Lee[4] and W. Cowen - University of Wisconsin

No report.

66. *Sediment Oxygen Demand*

Principal Investigator: N.A. Thomas - EPA

No report.

67. *Main Lake Macrobenthos*

Principal Investigator: N.A. Thomas - EPA

No report.

68. *Exploration of Halogenated Hazardous Chemicals in Lake Ontario*

Principal Investigators: G.F. Lee and C.L. Haile[5] - Texas A & M University

The sampling program was continued and expanded, and groundwork was laid for intensive gas chromatographic (GC) analysis of all samples collected and "cleaned up." Water samples were obtained from the Don, Niagara, Genesee, Oswego, and Black Rivers (major rivers feeding into Lake Ontario) in an attempt to add information concerning sources of halogenated organics to our ultimate overall data for the

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[4] Now affiliated with Texas A & M University.

[5] Added as Principal Investigator on this task.

lake. The 101 samples were collected at a depth of 0 to 1 m within 1/4 mi from the river mouths. At the sites, the samples were extracted by upflow (syphon) passage through columns of six DC-200 coated polyurethane foam plugs. A flow rate of approximately 250 ml/min was achieved. The columns were returned to Madison, where the plugs were removed, exhaustively extracted with hexane-ether azeotrope, and the extracts were then cleaned up.

Benthic fauna samples collected in January 1973 by S.C. Mosley, University of Michigan, on the *Limnos* were extracted and the extracts cleaned up for GC analysis.

Progress was seen in determining optimum gas chromatographic columns and column conditions for the bulk of the GC analyses to follow. Several columns were prepared, using liquid gases, such as OV-1, DC-200, OV-17, and mixed liquid phases, such as OV-17/QF-1, DC-200/QF-1, and OV-1/QF-1 coated on 80/100 mesh Gas-Chrom Q, 100/120 mesh Gas-Chrom Q, or 100/120 mesh chromasorb G packed in glass columns 5 to 7 ft long with an inner diameter of 2 mm. The columns were evaluated by use of standard pesticide solutions, pesticide cocktail solutions, and some Lake Ontario fish extracts. Columns showing high potential for separation with reasonable retention times include those prepared with DC-200, OV-17, OV-17/QF-1, and OV-1/QF-1. Column temperatures of 160-200°C were used with carrier gas flows of 7-35 ml/min.

Major among problems slowing our progress of this quarter has been a greater than anticipated difficulty in determining optimum GC columns and column conditions for the bulk of the analyses. Although this has caused some delay in the analysis, problems have been solved to a workable degree.

Final sampling should be completed next quarter with fish samples from major rivers feeding the lake added to provide information concerning halogenated compound sources for Lake Ontario. These fish samples will be extracted and the extracts cleaned up in the same way as the lake fish already collected. The bulk of the routine and exploratory GC analysis should be accomplished. Preliminary work on several confirmation techniques such as GC/MS, perchlorination, and TLC will be initiated.

69. *Basin Precipitation - Land and Lake*

Principal Investigator: J.W. Wilson - CEM

Derivation of precipitation data from the United States radar program is essentially on schedule. Reduction of the Canadian radar data, currently lagging, is expected to be on schedule by the end of the summer. The United States Data Sets 1 and 2 are now complete,

in terms of editing, error checking, and compacting of the raw radar data, and derivation of hourly precipitation totals. There are 1,150 hours that were not successfully collected on magnetic tape when precipitation was occurring over the lake. Of these, 925 hours can be extracted from PPI photographs or from overlapping coverage by the Woodbridge radar. Based on experimental results in extracting the missing data from film, a proposal is nearing completion to enlarge the scope of reducing these photographs.

Comparisons of radar and gage data during snow storms indicate the importance of studies to compare Oswego snow network data and radar data before establishing procedures to measure the water from falling snow. Such studies are being included in the proposal to widen the scope of this task.

Preliminary procedures were established by D.M. Pollock and J.M. Wilson for integrating the radar and gage data from all data sources to obtain daily maps of the precipitation over the lake and watershed. Results of radar and gage comparisons for Hurricane Agnes were examined in considerable detail. A report is being prepared.

70. *Evaluation of ERTS Data for Certain Hydrological Uses*

Principal Investigators: D.R. Wiesnet and D.F. McGinnis - NESS/NOAA

Melting ice has been detected in Lake Erie by comparing visible and near-IR differential reflectance and is being confirmed by meteorological ground truth data and concurrent NOAA-2 thermal IR data.

Using near-synchronous ERTS-1 data, we have determined the approximate ground resolution of NOAA-2's Very High Resolution Radiometer (VHRR) by comparing the smallest identifiable ice crack in the VHRR image. Cracks as small as 600 m are being detected. They are a high-contrast linear type of target.

Photographic interpretation and analysis of a single Lake Erie image (e.g., for February 18, 1973) can, under certain conditions, provide meaningful data on ice dynamics. Preliminary estimates of ice movement range from 800 m/hr to 300 m/hr (0.43 to 0.16 kn) to the west. A.E. Strong (personal communication), using the side lap on successive days of ERTS-1 passes, has been able to plot ice movements that range from 1500 m/hr to 500 m/hr (0.81 to 0.27 kn). Considering that time of onset of motion is not precisely known, these figures are in rather good agreement. It is significant that the wind inducing this movement was relatively light (10 kn or 18,500 m/hr).

ERTS-1 imagery is outstanding for ice-pack monitoring of the Great Lakes. Frequency of sampling interval (18 days) is, however, a severe limitation.

71. *Distribution, Abundance, and Composition of Invertebrate Fish Forage Mechanisms in Lake Ontario*

<u>Principal Investigator</u>: J.F. Carr - Great Lakes Fisheries Laboratory

No report.

72. *Coastal Circulation in the Great Lakes*

<u>Principal Investigator</u>: G.T. Csanady - Woods Hole Oceanographic Institution

Research objectives for this quarter were (a) further consolidation of the theoretical framework of lake circulation dynamics and (b) continuation of the analysis of the summer 1972 alert period.

In interpreting water movement observations, specification of wind stress from surface meteorological data remains a key problem. One theoretical study attempting to throw light on this problem is W.H.O.I. Contribution No. 3011, referred to in IFYGL Bulletin No. 7. This paper has been revised and accepted for publication in Boundary Layer Meteorology. A second study in the same general area has been prepared, "The Roughness of the Sea Surface in Light Winds," W.H.O.I. Contribution No. 3119.

Further work was done on the summer data. One puzzling feature of these is that considerable barotropic velocities exist perpendicular to shore. It appears that the coastal jet has a wavy or meandering appearance even along a relatively straight shore. Preliminary calculations indicate that the wavelength of these meanders may be of the same order of magnitude as could be deduced from a theory given by A. Robinson for Gulf-Stream meanders. Owing to the lack of alongshore resolution of coastal observations, however, it is not likely that this problem may be conclusively disposed of. A second generation of coastal chain studies should focus on exploring a piece of straight coast perhaps 50 km long, at several locations to describe alongshore variations of coastal jets.

Another aspect of summer, as well as the fall, data is the peculiar shape of the thermocline when it meets a sloping bottom, especially on occasions of developing upwelling. A nonlinear theory of this phenomenon is being worked on. The equations have been set up, but a suitable method of numerical solution has not yet been found. The difficulty is that boundary conditions at two points have to be satisfied, at the shore and at infinity, much as in boundary layer theory.

73. *Lake Water Characteristics*

Principal Investigator: A.P. Pinsak - LSC/NOAA

No report.

74. *Snow Observation Network*

Principal Investigator: R.B. Sykes - State University of New York, Oswego

No report.

75. *Lake Circulation Model*

Principal Investigator: J.R. Bennett - IFYGL Project Office/NOAA

Programming, checkout, and testing of model options is continuing.

76. *Lake Ontario Invertebrate Fauna List*

Principal Investigator: A. Robertson - IFYGL Project Office/NOAA

Work is continuing on correction of invertebrate fauna list.

77. *Natural Distribution and Variability of Physical Properties*[6]

Principal Investigators: E. Aubert, J. Harrison, and R. Pickett - IFYGL Project Office/NOAA

The objective of this task is to examine the temporal and spatial variability of physical limnological, meteorological, and hydrologic variables and derived variables, e.g., energy, transport, etc. Techniques will also be developed to produce data required for other tasks. An atlas of physical lake properties will be prepared. This task will start with July 1972 data. Techniques for application to other months will be developed.

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[6] This is a new task initiated in May 1973.

Project Areas

Boundary Layer - J.Z. Holland, U.S. Panel Cochairman

The Boundary Layer Panel held a meeting in Washington, D.C. on June 21 and 22, 1973. Before the meeting, principal investigators submitted a summary of their respective data collection dates, types of data collected, and project status. Four Canadian and two United States panel members attended. Representatives of the data management offices of both countries and of the U.S. IFYGL Project Office were also present. The data management representatives presented a summary of the data processing and availability status. Each of the principal investigators presented a report on the results of his analysis.

OPERATIONS AND DATA ACQUISITION SYSTEMS

U.S. Field Headquarters

The field operations under the responsibility of the U.S. IFYGL Field Headquarters were completed June 30, 1973. All land sites and buildings have been cleared of gear and returned to their original condition. The six Physical Data Collection System (PDCS) stations were disassembled. The equipment was checked and shipped to the Lake Survey Center (LSC) and the National Data Buoy Center. Post-calibration activities included temperature, dew-point, pressure, wind speed and direction, and electronic measurement unit tests at the Rochester facilities. Checks of the radiation sensors were completed by the Atmospheric Environment Service, Downsview, Ontario. Preliminary transfer of all data on cassette tapes to seven-track tapes was completed in Rochester. Equipment used in this transfer was then sent to CEDDA, Washington, D.C., for further processing of the PDCS data. After work at CEDDA has been completed, the equipment will go to LSC.

Positions of U.S. IFYGL Ships

Errata -- The station locations listed in table 2 in IFYGL Bulletin No. 7 (pp. 66 through 68) were in error in two instances. Latitude for IFYGL station identifier 66 should be 43°54'54"N. This position was occupied on and after June 13, 1972. Before that date, position was 43°54'36"N, 77°30'00"W. Latitude for IFYGL station identifier 70 should have been listed as 43°29'24"N.

DATA MANAGEMENT

Physical Data Collection System (PDCS)

> *Erratum* -- Figure 4 in IFYGL Bulletin No. 7 (p. 71) shows that data were collected from IFYGL station No. 27 (shallow tower off Rochester) for February and March 1972. This is in error. No data exist for this period from station 27 as the tower was removed from Lake Ontario in mid-November 1972.

In cooperation with the working team representing CEDDA and the IFYGL Project Office, the computer facility personnel at LSC have designed and written the programs necessary for processing the PDCS data. These programs have been tested and are becoming operational.

The working team at CEDDA has completed the interpretation and application of electronics and sensor calibrations and formalized the PDCS data conversion process. This process (see fig. 6) starts with 6-min raw data in the following forms: (a) real-time data (2-month disks), (b) RCC weekly tapes (seven-track magnetic tapes), and (c) cassette backup data. After the raw values have been handled and merged through software routines, corrections are applied for the various electronic units and sensor positions. The corrected raw data are then stored in the Provisional Data Base, with a source flag appended as a first digit (0 for real-time, 1 for RCC, a d and 2 for cassette data). Data that cannot be automatically processed are left out for possible later manual workup. Next, the data are converted into scientific units, and the resulting 6-min scientific values are then stored in the Provisional Data Base on disks, each containing 1 month of data. These can be written out as users' files at any time.

The reason for the order of the above process is that the PDCS electronics and the 15 sensor types were calibration checked independently in terms of input and output. The checks vary from simple "go"/"no go" operational checks to well-controlled multipoint calibration. Table 3 shows the availability of calibration data.

A first-order correction for particular electronics was applied to the raw data by means of the equation

$$R' = \alpha R + \beta, \tag{1}$$

where R is the raw data, R' the corrected raw data, and α and β are the linear transformation coefficients. Note that R is always a three-digit number, 000 to 999, and R' is always expressed as a number from 000.0 to 999.9. The coefficients α and β are functions of time, α being one and β being zero for ideal conditions, and are based on the performance checks

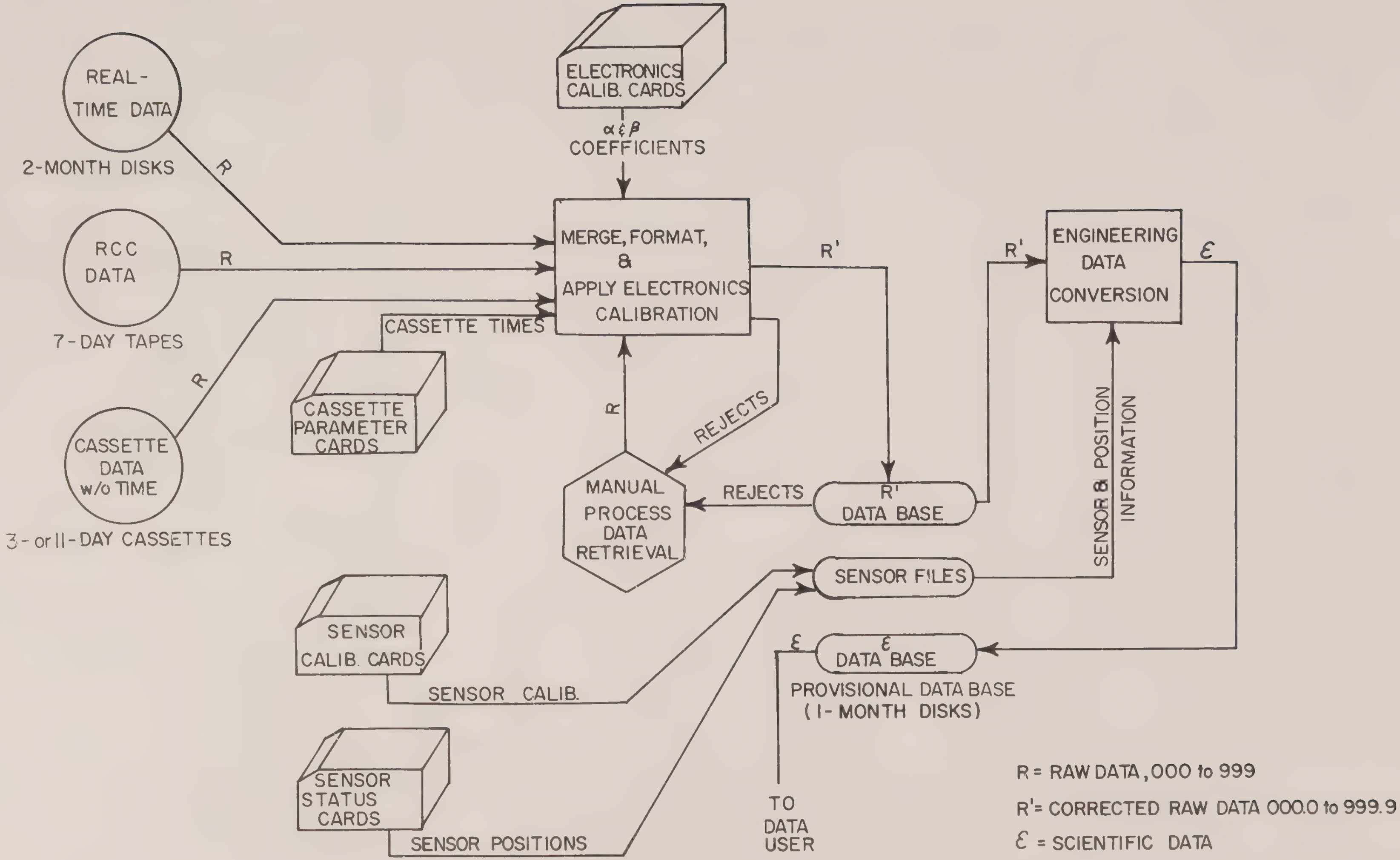

Figure 6. PDCS data conversion process.

Table 3. PDCS calibration data

Sensor Type No.	Parameter measured	Electronics internal calibration	Electronics performance check	Sensor calibration
01	Air temperature	x	x	x
02	Air pressure	*	*	x
03	Pan evaporation	*	*	
04	Precipitation	x	x	
05	Longwave radiation	x	x	x
06	Shortwave radiation	x	x	x
07	Dew point	x	x	
08	Wind direction (buoys)	*	*	**
09	Wind direction (except buoys)	*	*	**
10	Wind speed	*	*	**
11	Water temperature	x	x	x
12	Water temperature (evaporation pan)	x	x	x
13	Current direction (buoys)	*	*	**
14	Current speed (buoys)	x	x	**
15	Current speed (towers)	x	x	**

x - Data available and used in the PDCS conversion process.

* - No electronics internal calibration or performance check data available; analog-to-digital converter calibration check used in the PDCS conversion process.

** - Sensor calibration data available, but not applied in the PDCS conversion process.

Blank - No data available.

(electronic calibrations) and the internal calibrations that occurred automatically every 10 hours. Performance checks on all electronics were made both before deployment and after retrieval, and in some cases in the middle of the Field Year as well. They consisted basically of laboratory multipoint calibrations of the signal-conditioning circuitry and the analog-to-digital (A/D) converter and an operational check of the internal calibration feature, the digital circuitry, the recorder, and the radio. Since the electronics design relationships were known, the measured and calculated outputs were compared. The internal calibrations were two-point checks of the signal-conditioning circuitry and the A/D converter. The inputs were values simulating the sensors at approximately 90 percent and 10 percent of full scale; the outputs were the raw data values, called $R_{90}(t)$ and $R_{10}(t)$.

Data from the performance checks are tabulated as MD (measured data) versus CD (calculated data). This multipoint data set is fitted to a straight line by

$$CD = \gamma MD + \delta. \tag{2}$$

This equation is used in transforming the internal calibration values at the time of the performance checks to corrected base internal calibration values, called R_{90} and R_{10}. The actual internal calibration values during the operation of the electronics are used with the corrected base values (averaged from all performance checks) to form coefficients α and β in eq. (1). These coefficients for dew-point and air-temperature channels on land stations also contained linear corrections for differences in circuit design from the other stations. This was done so that in the next stage of the data conversion all stations could be treated alike.) Coefficients α and β were arrived at as follows:

$$\alpha = \frac{R_{90} - R_{10}}{R_{90}(t) - R_{10}(t)} , \tag{3}$$

$$\beta = \frac{R_{90}(t)\ R_{10} - R_{10}(t)\ R_{90}}{R_{90}(t) - R_{10}(t)} . \tag{4}$$

Based on a selected integer value with the lowest variance for that period, the actual internal calibration values, generally representing 1 month of operation, were chosen to be used with the corrected base internal calibration values. The errors resulting from this technique will be subject to study as part of the PDCS final data reduction.

The α, β correction of raw data consists essentially of starting with a linear transformation based on a multipoint laboratory check followed by monthly adjustment of this transformation using a two-point automatic check. The assumption is made that the two points from the automatic internal calibration at the time of the performance checks fall on the best-fit straight line of the performance check data and represent a base value from which drift or offset during actual operation can be calculated. If the internal calibration mechanism works properly, then the linear transformation can be adjusted based on the internal calibration values to a point where the transformation becomes the post-retrieval best-fit straight line. Note that some sensors did not have signal-conditioning circuitry (nor an internal calibration mechanism). In these cases a multipoint check of the A/D converter is used as the basis of α and β. (All data channels used the A/D converter.)

In conversion to scientific units, data were checked for values that were either too high or too low as a result of noise or serious sensor malfunction. The scientific data in the Provisional Data Base are indicated as follows:

-999.000	=	Internal calibration data
-999.000	=	Missing data
-888.000	=	Data out of range of sensor equation
-777.000	=	Data fail high/low check
-666.000	=	Transmission error; message not decoded properly
sFXXX.XXX	=	Scientific data; s = sign, F = flag, X = digit

The first step in converting the corrected raw data to uncorrected scientific units is the sensor-dependent linear transformation

$$E_0 = S_1 R' - S_0 , \tag{5}$$

where E_0 is uncorrected scientific data and S_0 and S_1 are the transfer coefficients. The subsequent steps, if any, are different for each sensor type. If the calibration is used, the correction for the particular sensor immediately follows the conversion to uncorrected scientific units. (Whether the sensor calibration is used depends on both the availability of sensor conversion information and the quality of the calibration data.) The data in corrected scientific units, called E_1, are a sensor-dependent function of the data in uncorrected scientific units as in

$$E_1 = f(E_0) . \tag{6}$$

An auxiliary step in conversion to scientific units is correction for the geographic location or position of the sensor. This includes correcting all direction readings so that they are referenced to true North, modulo 360, and correcting dew-point readings for the lead resistances. Atmospheric pressure is not corrected for elevation; it is reported as station pressure. Also, 950 mb is subtracted from all atmospheric pressure values. Rounding is to the decimal place at least an order of magnitude better than the system error. Table 4 summarizes the rounding, resolution, accuracy, and ranges for the 15 sensor types.

The complete Provisional Data Base includes all available real-time received data, input from RCC weekly tapes and cassettes, as well as data worked up manually to fill in gaps left by the automatic processing. For the Final Edited Data Base, after analysis and user feedback, as much erroneous data as possible will be filtered out and tapes generated in a format suitable for archiving, including hourly averages.

The Provisional Data Base will be complete on or about June 15, 1974; the Final Data Base, on or about August 1, 1974. Note that monthly segments of these data will be available in the interim.

Table 4. Summary of PDCS sensor ranges, accuracy, resolution, rounding, and units

Parameter measured	Sensor type No.	Design range (scientific)	Design range (raw data)	Design system accuracy	Approximate resolution	Round to nearest	Units	Comment
Air temperature	01	-25 to 40	000 to 999	0.5	0.065	0.01	°C	-
Atmospheric pressure	02	950 to 1050	040 to 760	0.5 (B) 0.2 (L,T,I)	0.125	0.01	mb	Expressed as station pressure minus 950 mb
Pan evaporation	03	0 to 10	025 to 714	0.02	0.01	0.001	cm	Total water level decrease with respect to full pan.
Precipitation	04	0 to 1.575	999 to 000	0.025	0.025	0.025	cm/6 min	-
Longwave radiation	05	0 to 4	000 to 200	0.05	0.02	0.001	ly/min	-
Shortwave radiation	06	0 to 2	000 to 200	0.05	0.01	0.001	ly/min	-
Dew point	07	-25 to 40	000 to 999	1.0	0.065	0.01	°C	-
Wind direction (buoys)	08	0 to 360	000 to 800	5.0	0.45	0.1	degrees of arc	Direction from; with respect to true North.
Wind direction (except buoys)	09	0 to 360	000 to 800	5.0	0.45	0.1	degrees of arc	Direction from; with respect to true North.
Wind speed	10	0 to 50	000 to 500	1.0	0.10	0.1	m/sec	-
Water temperature	11	-2 to 30	000 to 999	0.2	0.032	0.01	°C	-
Water temperature (evaporation pan)	12	-2 to 40	000 to 999	0.3	0.042	0.01	°C	-
Current direction (buoys)	13	0 to 360	000 to 800	5.0	0.45	0.1	degrees of arc	Direction toward; with respect to true North.
Current speed (buoys)	14	0 to 100	000 to 900	2.0	0.111	0.1	cm/sec	-
Current speed (towers)	15	0 to 100	050 to 950	2.0	0.222	0.1	cm/sec	-
Current direction (towers) *	--	0 to 360	- - -	5.0	- -	0.1	degrees of arc	Direction toward; with respect to true North.

* Current direction on towers is calculated from two orthogonal speeds.

U.S. PUBLICATIONS ON IFYGL

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